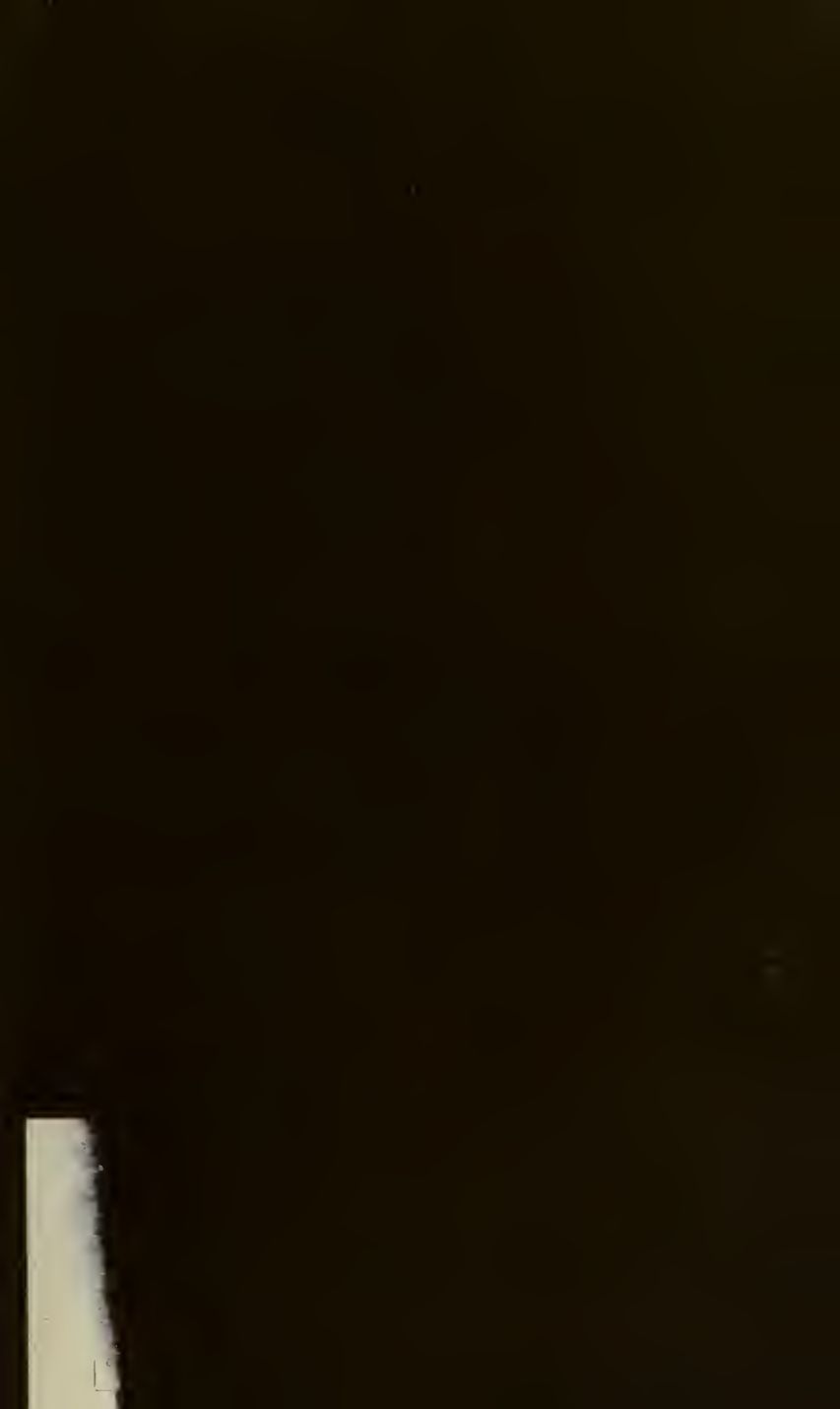


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MALARIA

AN ESSAY
ON
MALARIA AND ITS CONSEQUENCES

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PREFACE.

THE most of the contents of the following pages were thought out and roughly thrown together about a dozen years ago, when the author was still engaged in the exercise of his profession and possessed of opportunities both of observation and experiment.

In the course of his service in the Army it had been his misfortune both to see a great deal of Malarial Disease and to suffer long and seriously from it personally. And in the small practice, in a country district in England, in which he embarked on his retirement from the Service, it fell to him to have still further experience, both personal and professional, of the influence of, and the means of contending against, Malaria.

He claims therefore that the views, which he endeavours to explain in the following pages, whether eventually they be proved and accepted generally or not, are the views, not of a tyro, but of one who may not unreasonably be deemed somewhat of an expert. He now puts them forth in the hope, that they may receive the favourable consideration of the Medical Profession at large.

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MALARIA

AND ITS CONSEQUENCES.

SECTION I.—It seems at first somewhat difficult to speak in defined terms regarding a thing so occult, so vaguely known in itself, as that injurious condition of—or materies in—our environment, from which arise those peculiar injuries to health, which are recognised as “Malarial,”—which are generally, and not unreasonably, even if sometimes perhaps a little too exclusively, attributed to an offending “something” in the atmosphere,—a bad air,—a “Malaria.” But this term—Malaria—if not one which should command respect, as conveying of itself any accurate explanation of the real thing, which it is used to signify,—has yet become so convenient a term, by reason of the wide generality of its adoption and application only to that something, which is the cause of a well recognised series of conjoined and consecutive conditions of body, which are often far removed from being conditions of health, and by reason of its very vagueness, being such as not necessarily to commit its employers to any one theory of explanation; that it may safely be used by me, as signifying in a sufficiently defined sense the subject of the following pages, and it may equally satisfactorily be used by any, who may disagree entirely with my views.

It is then my aim in these observations to deduce, if possible, with some approach to distinctness and certainty,

somewhat of the real and essential nature of this condition or existence, thus conveniently spoken of as "Malaria." And in proceeding to do this, I observe first, that, among its most prominent characteristics, it is held by common experience to attach itself always to the same localities; it does not seem to follow any movements of population; it seems ruled by conditions affecting places, not persons, and to be permanently characteristic of those places. Malarial disease is not communicated from person to person, no person who has not been in a malarious locality ever receiving the disease from one who has. And in its local permanence there is never to be found any such varied and eventful histories as are met with in the records of cholera or enteric fever or any other zymotic disease; in its whole character and course it is different and distinct from any of these. The poison is not an infection, is not due to any communicable germ or bacillus; although it may be quite true that bacilli have been discovered in old sufferers from malarial disease, which have not been discovered or less abundantly in other persons, favoured in the former by conditions resulting from malarial poisoning, or by the malarial poison itself. And no one who has suffered from malarial disease, has ever incurred it otherwise than by receiving the poison for himself from conditions or materies existing in the place where he has dwelt.

This being so, it would be reasonable, first, to endeavour to determine the mainly prevailing characteristics of places, where malaria is found to abide, and the phenomena that seem to distinguish them as a class from other places; next, with some detail to investigate and estimate what might be the results on physical health, that might intelligently be looked for, on known principles, from exposure to such characteristics and phenomena, each separately

considered. It would be possible thus to open up a field of discovery and inference, wherein one might arrive both at safe conclusions as to the real nature of the "malaria" and at a reasonable basis for a scientific medical treatment of its effects.

This then, in short, is the scheme which it is my purpose to follow; and, in commencing, I think it well to premise that for the present I put aside from me any idea that, in the air, water, or soil of places which are under the insalubrious domination of malaria, I have to discover any new constituent, such as is not to be found in other places. I shall be satisfied first to examine in what respect or degree the normal relative proportion may be departed from of constituents that are of usual occurrence; and how far, or in what way, any such departure so discovered may have power to influence and cause injury to health. It will be open after that, if desired, to inquire further whether there may exist in malarious localities some other, new or unusual, materies, unknown to localities not under the dominion of malaria, to which the evils of malarial disease may be attributed; but one line of inquiry is enough at one time.

Malaria, has been stated (Parkes) to have been found over marshes, with some exceptions; over large collections of vegetable matter in the soils of valleys, &c.; on sandy plains, in which is an admixture of organic matter; on some weathered and disintegrated rocks, in which vegetable matter has become intermixed; and on the lower parts of the chalk, &c. While it is unquestionable also that it is found in great force in, or near, many natural jungles in India and densely wooded lands elsewhere; and that it is maintained and intensified by the absence of disturbing winds.

In considering the nature of these several situations

and striving, in accordance with the scheme I have laid down, by an examination of the ordinary constituents found therein, to ascertain what that peculiarity may be, on which depends their malarious character, it will be convenient and proper to give our attention, and I shall endeavour to do it as exhaustively as I can, first to the atmosphere; because the accepted term "Malaria" primarily directs attention to it, and because, more than can be estimated to belong to the water supply or to the soil, the atmosphere has a continual, direct and extensive bearing on the economy and welfare of animal life. Next, the water and the soil are, without question, important factors in the salubrity of all places, whether directly or indirectly; and I shall return to consider the nature and extent of the influence attributable to them in the production of Malaria.

The ordinary components, then, of the atmosphere, whose nature, distribution and actions we are to consider, are nitrogen, oxygen, carbonic acid gas, and aqueous vapour.

The first of these, nitrogen, is said to possess of itself no active properties in relation to animal life, whether for good or evil, but to be only a bulky diluent of the more active ingredients. In composition, however, it is not so absolutely inoperative; and it is thus detectible in very minute proportion, in ammonia existing in the atmosphere; also, in the presence of certain electrical conditions in nitrous acid. The ammonia thus detected is such a mere trace and probably perfectly harmless, both in respect of its own nature and of its minute quantity, that it may be set aside from further notice. The nitrous acid may possibly be more deserving of remark from its readiness of chemical action on other matters; although I am not aware of any recorded observations, from which to judge, otherwise than speculatively, of such action; and,

from the circumstances of its production, its presence can only be of an occasional kind.

Oxygen, the next most abundant constituent of the common air, is that element on which the processes of health are most dependent. And it is never, at any rate in the state of dilution in which it is received from the atmosphere by respiration, credited with other than a beneficial influence on health. At the same time it is to be remarked, having respect specially to the present subject of inquiry, that the presence of a plentiful supply of oxygen, or even of its more active allotrope, ozone, has not been found to diminish or clear away the morbid power of malaria. From these circumstances I conclude, first, that the material of malaria is not referable to the oxygen in the air; and second, that this material is not one that is susceptible of oxidation, which would be equivalent to its conversion or destruction; this latter conclusion being one which may be of further value in this inquiry.

Carbonic acid gas is the third in order of the components of the atmosphere. And in contemplating its distribution, its essential properties, and the possible extent of its effects on animal life and health, a wider and more fertile field opens to our investigation. This gas is notoriously a deadly poison, when mixed in large proportion with the air of respiration; and 'is very hurtful to animal life, even when largely diluted with air.' It is stated that it exists ordinarily in the proportion of '3·7 measures to 6·2 measures in 10,000 measures' of air; that 'relatively its quantity is but small, but absolutely it is very great, and fully adequate to the purpose for which it is designed, namely to supply to plants their carbon, these latter having the power, by the aid of their green leaves, of decomposing carbon dioxide, retaining the carbon and expelling the oxygen,—the presence of

light is essential to this effect'; that it is constantly generated where organic matter is in the act of undergoing fermentative decomposition, also it may be evolved by decomposing a carbonate with one of the stronger acids; and that the proportion of it in the air, 'being much influenced by local causes, varies considerably.' In view of these statements, therefore, the significance of which in relation to our subject cannot be considered too highly, let us inquire what sort of places those are, in which it may be either ascertained or reasonably expected that an extraordinary proportion of this gas is present in the atmosphere. Other inquiry may then follow, whether, in its distribution, or in any other characteristic, there is discoverable any relation or similarity of behaviour between this injurious gas and the sought for materies of Malaria.

A great variety will be found to characterize the situations in which it may naturally be supposed that carbonic acid gas will be abnormally abundant in the atmosphere. Over marshes and lakesides, according to the amount of dead vegetable matter and the degree of moisture and temperature favourable for promoting decomposition, the production of carbonic acid would be expected, while the continued presence of it in the air would also depend on the insufficiency of the natural consumption of it by growing vegetation, the amount of water present which might absorb it and keep it in solution, and other influences. Other gaseous products no doubt, besides carbonic acid and that which has by consent received the distinctive appellation of "marsh gas," which may be looked upon as a potential source, by further decomposition, of more carbonic acid, may be evolved, as, for instance, sulphuretted hydrogen, but of this in relation to the subject of my inquiry it may be deferred to speak until a later time. More prolific perhaps, however, in the evolution of car-

bonic acid, than very wet marshes, are some other situations; where a less extensive level of surface, more shelter from wind and sun, greater abundance of successive vegetation, and less active circulation of local moisture may obtain and may promote the more continued and thorough decomposition of dead matter,—as low grounds in confined valleys, with a rich soil, and set in deep woodlands or sustaining a lower growth of a bushy or broad-leaved character. But the variety of such places is too wide to admit of a good brief classification of them,

To reason conclusively, *a priori*, of the probable evolution and retention of carbonic acid in the air of any place, and of its abiding vitiation by that injurious gas, one must take into due account the proportionate value of a series of natural conditions of the place, conditions which, were they in perfect balance, would probably preserve the wholesomeness of the air. In some places, such as I have indicated, there may be a considerable display of greenleaf and much exposure to sunlight, the two leading factors in the consumption of the carbon of the acid by plants; and still, withal, the amount of decomposing vegetable debris, under the influence of moisture and a favouring temperature, may be there so great, that the evolution of carbonic acid exceeds the capabilities of these factors to convert it, and there remains in the atmosphere unused a large amount, as hurtful to animal life as it is unrequired by vegetable. In other places a very different balance of conditions may obtain, which will yet have a similar result; in some the absence of the wholesome agency of green leaves may be the preponderating condition favourable to the accumulation of carbonic acid gas; while in some it may be the want of a sufficient measure of sunlight. And there are other local circumstances, which in different ways would have influence on the

amount or the constancy of carbonic acid in abnormal excess in the local atmosphere; as the immediate neighbourhood, or the absence, of running streams of water, by which some of the acid would be absorbed and carried safely away; or, the open and elevated nature of the situation, exposed to free large currents of air, perhaps even to high winds, which would drive away and dissipate the hostile gas.

It may be well, however, to indicate with somewhat more particular detail some instances exemplifying such characteristics as have been referred to above. There are large alluvial surfaces, of more or less recent creation, containing sometimes a very large proportion of imperfectly reduced vegetable matter in the alluvium, frequently liable to the shedding of a degree of moisture over them capable of promoting a more perfect decomposition; which are freely open to the action of the sun's rays, but are devoid, or almost devoid, of any effective presence of green vegetation. The most recent and the most perfect examples of such surfaces, which I bring to mind, are the extensive mud flats which have been deposited and are still in process of enlargement along the courses of mighty alluvial rivers such as the Ganges. While, somewhat differently from these, as being of a less recent formation and being somewhat less overflowing, though perhaps as regularly, impregnated with moisture from time to time, the plains of India, where the soil over very wide extents is composed partly of a fine sand and partly of a mud which still contains much organic vegetable mould recurrently awakened to a resumed decomposition by "the rains," are instances essentially similar. Again, there are well covered countries, with woodlands and much luxuriance of growth, of low altitude relatively to the sea level or to elevations in the near vicinity, where much swampiness

may also exist, and here there are all the means and opportunities of a very abundant evolution of carbonic acid. Perhaps the most impressive of such instances, that I have known, is the Island of Singapore; in the jungles of this island, there may be described, as their common constitution, —an upper stratum of umbrageous forest trees of large growth and lofty foliage; a second stratum of a thick and somewhat tangled lower growth, perhaps from 10 to 40 feet above the ground; and again, under this a third stratum, a matted collection of shrub and climbing plants of smaller growth, ferns, broad-leaved calladiums, and many others such-like, entangling fallen foliage and debris, and covering from sun and wind an ever-collecting and ever-decaying mass of vegetable matter, lying on, and eventually combining with, a wet and reeking soil. But in our own country also there are districts where the same conditions are present, though, not on the same scale as in Singapore; and beneath the shade of a vegetation so ordered, where the moist ground becomes loaded with fallen foliage and other vegetable debris, the generation of an extraordinary amount of carbonic acid is inevitable; a small proportion of which is, no doubt, utilized by the green vegetation in its midst, and a little may be taken up and drained away in the moisture around, exerting probably some little degree of antiseptic power over the mass which it impregnates; but the chief part of which is retained, more or less permanently, in a dank, almost stagnant atmosphere next the ground, below the sunlit level of the greener foliage, to issue thence slowly, but surely, in virtue of its diffusive power as a gas, to poison the locality around.

There is another kind of country, one chiefly of undulating contours and rolling downs, of which an umbrageous vegetation is no leading feature, which is well instanced

in southern parts of England; of whose soil the foundation and prevailing constituent is chalk. And in this formation we have incalculably vast store-houses of carbonic acid, which is retained there in combination with lime. While it is so retained—while it is present only in that proportion in which true chemical union remains perfect, and there is no such excess of it in relation to the lime as, in the presence of moisture, to produce a soluble and therefore potable compound—it is harmless enough. If there be present in the immediate atmosphere or in the moisture of the surface any active quantity of free carbonic acid, some of the chalk in contact with this will be dissolved and carried away into the water supply of the locality; which will come to be considered by and by in its own place. But if the circumstances are such, that the chalk is not dissolved, but is decomposed and the carbonic acid set free as a gas, say by the invasion of some other acid, it will then be shed into the atmosphere and work the same injurious effects as if generated by decomposition of vegetable matter; and the presence of such an invading acid it is not difficult to conceive. It is said by Parkes, that nitrous acid is formed in some quantity during electrical storms; and a long high range of chalk “downs” will sometimes, as I have repeatedly seen, attract to themselves and apparently lead in the direction of their own length the chief manifestations and force of such storms. It has, again, been shown by Cloez, that air taken about one metre above the ground often contains nitrous acid in sufficient quantity to redden litmus. Further, it is not unreasonable to speculate that in some of the operations of husbandry on tracts of chalky soil under cultivation, or in the necessary circumstances of human habitation, some other reagents may be brought to act upon the chalk and have the same effect. So then it may reasonably be

concluded that carbonic acid is pretty abundantly set free from a large chalk formation by the action thereon of probably more than one chemical reagent; while it is certain that in the process, which is common in chalk districts, of obtaining lime from the chalk by burning it in kilns, it is set free in large volumes; and it may very readily be expected that in these districts, besides all that the decomposition of vegetable matter therein may yield, a very large and injurious amount of carbonic acid is continually being disengaged and floated into the atmosphere.

When the air becomes loaded with so heavy a gas as carbonic acid, the gas naturally inclines by its own relative weight to subside into the hollows and the lower levels; and, when it is in these places that it has been generated, it is not easily dislodged from them. In such situations, then, were it not for the diffusive power of the gas, which it does possess in common with other gases, though but in a low degree, and if the force of wholesome winds did not prevail to second the diffusive power pretty effectually, the carbonic acid gas would collect in the atmosphere there in such quantity that all animal life would be extinguished.

Summing up these conclusions,—an abnormal quantity of carbonic acid, which in its own nature is very hurtful to animal life, however beneficial and necessary to vegetation; the proportion of which, in the air in which we live, varies considerably in different places in accordance with local causes; will be found to be most abundant in the following situations:—over marsh lands, where the succession of unremoved vegetable growth entails a perpetual presence of much superseded and decomposing vegetable matter; over alluvial tracts, comparatively recent or of ancient formation, which contain in their soil a large quantity of imperfectly reduced components of vegetation; in the deep

interiors or near the shaded borders of old, dank, luxuriant jungles or woodlands; in the valleys and lower levels in or around extensive chalk formations; and, in any of these, in greatest intensity, and therefore most hurtful, in the lowest levels and the most confined hollows and recesses, and in those parts where these favouring conditions have been of longest standing.

But the types of localities here set forth, differing the one from the other, are identical with those, also mutually differing, in which it has been well ascertained that Malaria most abides and wields its baneful power. Confirming this coincidence, Parkes says, "the air of typical marshes contains usually an excess of carbonic acid, which amounts to $\cdot 6$ to $\cdot 8$ or more per 1000 volumes;" and I am able to extend considerably his statement from the results of direct experiment, which I carried out, in the manner prescribed by him for the estimation of carbonic acid in the air, in the very malarious district in which it was my fortune to find a practice after my retirement from the Service,—a district in which there are many marshes of small extent, which is set in luxuriant woods of dense and diversified character, and which lies in the midst of an extensive tract of chalk, with lofty chalk downs overhanging it; where sometimes strong gales sweep the miasmata temporarily away, but where also sometimes there reigns an absolute stagnation of the atmosphere. In these experiments, the times and sites for which I chose with careful consideration in respect to obtaining illustrative and significant results, and which were conducted with much painstaking accuracy, I found the carbonic acid in the air, at from about two to three feet from the ground, to vary from $\cdot 2$ to $1\cdot 8$ and more per 1000 volumes. I also found that those times, when my practice made me aware that Malaria was most oppressing the population, coincided

very remarkably with the times when the carbonic acid was in greatest excess in the atmosphere. And further I found that these times also coincided generally with the registration of high readings of the barometer.

Parenthetically I may mention, although it is not directly in the line of my inquiry, that from this last circumstance I was led to infer that the diffusive power of carbonic acid gas, which is comparatively very small, or of the malaria, is great enough to cause its excessive presence in the atmosphere to extend to a great height, to such a height at least as by its specific weight to increase palpably the weight of the column of air pressing on the barometer; and from this I was further led on to this meditation on the east wind, as we are acquainted with it in this country—it is almost invariably inveighed against; it may be abused differently by people of different susceptibilities, but it is almost always characterized as aggravating and depreciating the physical well-being—also, I think it is the case, though I have not myself made any investigation of the statement, that in an east wind the barometer maintains a higher reading than in a wind of the same force from any other of the cardinal points of the compass;—putting these circumstances together, is it not open to draw an inference that this wind may, as a necessity of its origin, be charged with a greater quantity of carbonic acid than the others, which it has derived from the surface of the extensive, wood and swamp and waste bearing continent that lies eastward from us?

But a fourth ordinary constituent of the common atmosphere awaits consideration. This is watery vapour; which of itself is altogether non-poisonous, and is capable of doing injury to health only by affecting the temperature of the living body, either too depressingly, or too rapidly; although it is plainly possible that it should act as a

carrier to something else, gas or vapour, which may not be so innocent. There are many localities where it is habitually present and prevalent in very large amount; and it is there often credited, and on good grounds, with being the cause of grave ailments, chiefly however from its facilitating hurtfully rapid changes of surface temperature; the characters of any of these ailments are not at all those which distinguish the forms of impaired health that are referred to, and are evidences of, malaria. There are localities on the other hand of malarial reputation, which are known to be malarious when no excess of aqueous vapour is present, but where fogs sometimes arise and spread across the landscape with remarkable density; and these are then associated in the common estimation with the dreaded malaria, apparently giving it a body appreciable to the eye, and really enhancing the severity and prevalence of the malarial disease. They are often seen in malarious places, especially at night or in the early morning, advancing in trailing wreaths along the face of the country, up gentle inclines from more thickly misty valleys, clinging to and apparently helping themselves on by means of coverts or hedges in their course,—behaving indeed as if there were an alliance between them and some heavy emanation in these coverts and hedges; and these fogs assuredly often bring with them an added momentum of malarial malignity. But there seems no feasible ground for regarding themselves, for regarding the watery vapour itself, as anything more than a means of conveyance; by which the malaria is conveyed hither and thither in more quantity, made to envelope its victims the more closely, and introduced, as by a therapeutic vehicle, the more solubly into the living animal system.

Three, therefore, out of the four ordinary components

of the common air, may be put out of court in the inquiry as to the identity of malaria—nitrogen, oxygen and aqueous vapour; although the last of these may yet be held to have some relation to it, both as a bearer of it, and as a factor in its creation. But the fourth ordinary constituent of the atmosphere, carbonic acid gas, has been found to coincide in a remarkable degree with some of the circumstances of malaria, the characters of the localities in which the one is found to be most rife and the other is most liable to be evolved or stored, and the character common to both of being hurtful to animal life.

I turn now for a brief space to consider what may be chargeable, of any probable cause of the malaria, to the water-supply of those localities where malaria is characteristically present—to the water of natural marshes; of paddy fields; of forest lands; of jungle settlements; of alluvial flats; of malarious situations on, or impendingly neighboured by, chalk. In some of these places, as in the immediate foci of human habitation, or where cultivation of the soil is carried on, there may be matters of an organic nature in the water, very dangerous to the health of those who drink of it; but, as has been pointed out before, the characters of disease that malaria produces are quite diverse from those of diseases, such as cholera, typhoid, diarrhœa and such-like, which are caused or propagated by germs or matter possessing an organic constitution and a zymotic energy, and it is therefore irrelevant to the present purpose to investigate these. The inorganic matters that may be found in the potable water of malarious places may be inferred from the physical characters and relations of the places. Classifying these into two general classes,—those in which the distinguishing common character is the presence, in or on the soil, of much imperfectly decomposed and decomposing vegetable

matter; and those which, with or without some degree of this character, are noted as deriving a baneful, malarial influence from resting on, or lying near, important deposits of chalk,—it will not be difficult to pre-suppose what some of the leading inorganic matters in the water of these places would be. In those places where, in whatever recent or ancient stage it may be, the presence of the decomposition of a large quantity of vegetable matter is the character on which the malaria seems to depend, it may reasonably be expected that in the water we should find a large amount of so prominent and so soluble a product of vegetable decomposition as carbonic acid; it being stated that ‘cold water dissolves about its own volume of carbon dioxide,’ and that ‘the solution temporarily’ (*i.e.*, until the paper becomes dry and the carbon dioxide is dissipated) ‘reddens litmus paper.’ There may, here and there, be other inorganic matters to be found also, but none other seems to have any special or important association with any feature essential, or peculiar, to a malarious situation of this class. Again, in the malarious places which seem to derive their malaria from the chalk, it would be only natural to suppose that a large amount of the chalk, dissolved by a great excess of its own acid, furnished as before described, would be carried away in the water, and most probably also a further large amount of carbonic acid retained free in the water in solution. Such water is called “hard,”—a term commonly understood,—and it is a common fact that the water of chalk districts always is hard. But in regard to this I may be permitted to refer to a not infrequent inaccuracy of expression, or perhaps misapprehension; the hardness of water is often spoken of as being due to the lime, or sometimes iron, held in solution; and it is due to them to the extent that they are the bases in combination; but it is not due to them in the sense that

it is in them that the hardness consists,—it is in the excess of carbonic acid required for the solution of their carbonates that the quality of hardness lies. In the hard water coming from the chalk, in the district of my late practice, I have repeatedly proved the presence of a large excess of acid by the marked degree of redness produced by it on litmus paper; on the other hand, if hydrate of lime be added to pure water, even in large quantity, it will not be found that the water is thereby made hard. Moreover, I think that the water drawn from the soil of districts, where the decomposition of vegetable matter is the attributed cause of malaria, would be found to be hard also, notwithstanding that there may be no chalk in the region.

I should now refer to the soil of malarious places. But,—except the influence, which may indeed be of serious consequence, that it may have on the general temperature and its alternations, acquiring from the sun and imparting again great heat through the day, becoming very cold again by radiation when the sun has gone down and imparting the chill through the night, which will probably come to be enlarged on afterwards,—the soil can have but little effect on the health or on malarious conditions, unless through the air or the water, by gases or vapours shed from it into the former and by substances of free solubility imparted to the latter; and these have already received attention. It is therefore unnecessary to dwell on it further.

From what has been stated thus far, then, the presence of much carbonic acid, actively abounding in the air and the water, and derivable from the soil, is a natural characteristic of the same places, to which malaria gives a bad character; and, where carbonic acid is a prevailing yield of the natural features of the situation, there also the evil presence of malaria is felt. It is also known, by careful

study of no recent date of the properties of carbonic acid gas on the one hand, and by a widely collected experience in regard to malaria on the other, that they coincide in a common hostility to animal well-being. Is it in our power to adduce any further, more intimate, coincidences of a similar or identifying significance between them? What do we know, and what further may we find means of prognosticating, of the manner of the malign action of carbonic acid? and what is the manner of the action of malaria, what are the details of its operation in malarial disease?

SECTION II.—It has already been quoted, that carbonic acid is “very hurtful to animal life, even when largely diluted with air;” and we have the still more pregnant statement, on which I shall have to dwell a good deal hereafter, that it “extinguishes combustion,” or, in other words, that it arrests oxidation, a process which is essential to the existence and continuance of animal life. But we have also particulars, recorded for us by writers on Medical Jurisprudence, of the phenomena that occur before death, and of the post-mortem appearances, that have been observed in fatal cases due to this poison. It may be wished, that these particulars were more full and suggestive than they appear, and that more extended chemical, as well as pathological, research revealed more. But from what has been given to us there may much be fairly deduced, that will illustrate the actual way in which carbonic acid does attack and subjugate life.

One of the most prominent of the facts, that appear from the records, is that of the remarkable diffusibility through the organism of the poison and the rapidity with which it invades every part of the system. The entire process of death takes but little time; and yet, from Taylor’s account of the appearances after death, the poi-

son seems to have permeated the whole body,—the cutaneous surface, the venous system, the lungs, the brain, the intestinal canal,—and left signs of its action in the heart.

Another fact appears to be that, in the early stages of the process of poisoning, the behaviour of the carbonic acid is that of a direct irritant of the nervous system. It is said, “the action of the heart on the first accession of the symptoms is very violent,”—“sometimes accompanied by pleasing sensation of delirium, while at others the most acute pains have been suffered”; “in some instances there appears to have been irritability of the stomach, for the affected person has vomited,”—while “those who have been resuscitated have often felt pain in the head or pain and soreness over the body for several days.”

Of most of the other phenomena, recorded by Taylor, the main cause is to be found in the property of carbonic acid to which I have first alluded, which is its most powerful and subduing property—that power of arresting oxidation. This is the power, that causes the blood to remain unoxidized, unbrightened, in the veins; that robs of vitality the blood-vessels themselves, preventing them from sending onward the blood in their accustomed way and leaving the left side of the heart at last unfilled; that deprives all the muscular system of its tonicity and capacity of vital action; that clouds the brain, induces coma, overwhelms all sensibility, and ends in death.

But there are two circumstances mentioned, which are worthy of a little separate consideration;—“the body of a person who has perished from the inhalation of carbonic acid is said to retain the animal heat, *cæteris paribus*, for a longer period than usual,” and “cadaveric rigidity does not commonly manifest itself until after the lapse of many hours.” I think it is possible to suggest some reasonable explanation of these circumstances from what we already

know of the actions of carbonic acid in the other symptoms and appearances recorded. It is hardly to be wondered at, if the property in the poison of arresting oxidation, thereby arresting vital action, should delay, or even if it should in some cases altogether prevent, the cadaveric rigidity of the muscles; for, though this is an occurrence that is subsequent to the consummation of the death of the person as an individual animal, it is still a vital action, that occurs before the absolute organic death of the muscular structure which is but a part of the animal. Moreover, the unusual flaccidity is only a temporary continuance, during the existence of the remains of organic vitality in the muscles, of the same condition of "loss of muscular power" which was a symptom in the earlier stages of the poisoning; which probably was due, partly to the irritation, involving some degree of exhaustion, of the innervation, and partly to the numbing arrest of oxidation and vital action. Again, the retention for a longer time than usual of the animal heat may be due in different degrees to the influence of two causes in combination; first, the existence of a higher, than normal, temperature before death, which would have accompanied the irritation of the nervous system, already referred to, and would have occurred, partly as a secondary result of this, and partly due to the direct and intimate influence in the tissues of a poison, whose simple quality of free acidity would be an exacerbatng and heating agent;—second, the retardation by the poison of the exhalation of the heat, either natural or thus increased, of the body, for the exhalation of the body heat is not only a process of convection from a warm to a cooler surrounding medium, it is also in some measure a vital process, the last vital process of organic change, and in this respect would be delayed as other vital processes would be, by the arrest of oxidation in the presence of such a poison.

I cannot quite accept, with the precision and limitation which it implies, the conclusion at which Taylor arrives,—that carbonic acid acts (as a poison) by inducing apoplexy or cerebral congestion. This conclusion seems to be drawn from a partial view of the appearances previously described, giving preponderance chiefly to the congestion of the membranes and great vessels of the brain and to the serum found in the lateral ventricles. But if we take a wider view, and balance together all the appearances, placing them in the probable order of pathological sequence, a different and more particular conclusion seems possible. It would be expected that an inhaled poison would commence its action in the lungs. This poison, which is possessed of the inherent property of stopping oxygenation, would immediately in some degree arrest the function of the lungs, which is the oxygenation of the blood; by doing so it would further tend at least to stop the current of the circulation there, both from the failure of the necessary stimulus of aeration in the blood itself, and from hindered or weakened vital action in the blood-vessels and the lungs; and thus we should find the vessels of the lungs in a state of congestion and the lungs gorged with dark blood, as they are described to be found. This stasis of the circulation, which would be growing every moment in immobility, would communicate itself backwards, to the right side of the heart first, then to the whole systemic venous system, and would then affect the whole of those parts, especially the softer and more cellular tissues, whose condition depended in any degree on the relief of their fluids by the veins; and we should find the right side of the heart containing dark blood half coagulated in virtue of its want of current movement, the venous system filled with blood of a dark colour, congestion of the membranes and great vessels of the brain; the skin af-

feeted in colour by the preponderance of dark venous blood and the want of blood of the brightened arterial tint, covered by patches of a violet hue or extremely pale, the countenance livid, dark ecchymosed patches in the intestines; the whole body appearing as if it were swollen, eyes prominent, swollen tongue, and serum in the ventricles of the brain;—appearances which have been described to have been found. Finally, this stasis causing all the right side of the circulation to be filled to plethora, the left side would be imperfectly filled, and at the heart the last stimulus of arterial blood would cause a final effort to be made by the left auricle and ventricle to continue their function and send on their last remaining fill of blood, not again to be renewed; the left sides of the heart would be found nearly empty;—and this again is the appearance recorded after death. Tracing thus its action according to the pathological sequence which appears to me to be shown by the phenomena that are recorded, I conclude that the fatal action of carbonic acid inhaled begins in the lungs, and ends at the left side of the heart; that, as incidents in its course, which is directed chiefly by the circulation of the blood, it causes the physical changes, recognizable mostly after death, which are detailed by Taylor, and which I have sought to arrange in natural order; but that also, during its whole course, it retains and exerts in every part or tissue, to which it is conveyed, the specific character of poison, which belongs to it from the first,—that of quenching combustion or oxidation, arresting vital processes, and putting out the flame of life.

Phenomena, however, of such marked and violent character, as have now been treated of, belong only to instances in which the carbonic acid has been inhaled in such overwhelming quantity as to be speedily fatal, to cases of mortal catastrophe that engage the interest of

medical jurists, more than the attention and the endeavours of the physician. And yet the properties of free carbonic acid are the same, in whatever strength or dilution it may be present; its character and action as a poison are unchangeable. Nor can it be of consequence in what manner it is introduced into the body, whether by inhalation as in Taylor's cases, or in some other way; its essential nature and the necessary effects of that essential nature on living animal tissue will be fundamentally the same. The only difference, between its action in catastrophic cases, as detailed above, and its action in cases in which it is only very gradually and in very small quantity introduced into the system, will be a difference, not of kind, but of degree. Is it possible then to deduce, from what we have already gathered and from concomitant incidental considerations, any full and reasonable conception of the consequences of its action, when acting thus slowly, gradually and in very small amounts?

Besides the fact that carbonic acid is present in a small amount in the atmosphere that we must constantly be breathing, we know that it is a fact of our constitutions that the oxidation of our tissues, through the instrumentality of the blood, which is always going on in our bodies, results in the continual generation of carbonic acid, and that the means provided by nature for voiding this from the system is expiration by the lungs. This expiration, any effort of which would probably be unequal to the absolute evacuation of all the carbonic acid gas awaiting discharge, proceeds through bronchial tubes, which are, in health, always lubricated with a certain amount of moisture; and this moisture has the capacity of taking up into solution and imparting to the tissues around a portion, however small, of the carbonic acid which is being expired through them; it follows then that the full rid-

dance of the system of free carbonic acid is never altogether, adequately to its generation, effected. And when we think, that in the air we breathe we are always inhaling a little, that the combustion of the tissues of our bodies is always generating more, and that the expiratory apparatus is always retaining a minute proportion of what it endeavours to expel, we cannot but suppose that, as days and years advance, our bodies must come to hold in them a larger and larger amount—small even though it may be—of this most pernicious product. It is therefore to be concluded that the constitution of an aged person would be more impregnated with free carbonic acid than that of a young one; and that the effects of its presence, whatever they may be, would be more easily discernible by a considerate observer in an aged, than in a youthful, subject. What then would these effects be? What are the effects, which in the rough we think we have ascertained in the preceding pages to follow the action of a large amount of free carbonic acid in the body? The same effects, identical in their specific nature, though not at all of equal magnitude of result, will follow also where the impregnation by carbonic acid through advancing years is very slow, small in quantity, but very persistent; and will probably be in approximate proportion to the quantity and persistency, sometimes so small as to escape recognition, and sometimes tolerably clear and marked.

The apparent characteristics of the poisonous activity of carbonic acid may for convenience be classed under three heads:—1. Its speedy diffusibility through every part of the body; chiefly by means of the circulation of the blood, but possibly also, in a supplementary way, if with less speed, by communication through contiguous moisture of tissues;—2. Its irritating and exasperating, and by reason of this its exhausting, influence on the ner-

vous system ;—3. The paramount essential characteristic of carbonic acid in relation to life of animal tissue, animal function, and animal living existence ; that it extinguishes, partially if not completely, that combustion or oxidation without which animal life cannot continue or exist.

From the first of these, we should not be prepared to expect that the action of a small quantity of carbonic acid, increasing slowly with continual, but very small, additions in the course of years, would show any special tendencies of localization in parts of the system, other than might occur perhaps from some superior capacity of accommodation or presence of moisture, which the tissue of one part might have more than another. It would affect, as near equally, as possible, the whole system.

From the second we should anticipate that, as in the cases of sudden and violent poisoning spoken of by Taylor, but with less of violence, the temperature of the body would be raised, at times possibly to fever heat. I have attributed this result in the fatal cases recorded to the natural effect, chiefly on the nervous system, but no doubt also on other structures, excited by the simple quality of acidity of the poison present in them. The effect of this quality exerted on the nervous system, even if the carbonic acid be of comparatively small amount, if continually being increased, would be a greater or less degree of suffering, as long as any keenness of sensation remained, from irritation, inquietude, instability and weakness of the whole nervous system ; some of the observable symptoms of which would be—loss of energy and steadiness of muscular power, tremulousness, pain, facile excitability, restlessness, failure of the faculty of sleep, loss of power of endurance and of mental attention, diminished ability to resist or to regulate emotional disturbance. And in other tissues than that of the nervous system, being present in

all of them, it would have the same action on them in the degree and in the manner in which they are capable of being so acted on. It is a quality that would naturally exacerbate any function or process of change belonging to organic tissue; would accelerate and aggravate the natural waste of tissue, and would impede the function belonging to the tissue and structure. Yet there are bounds beyond which this irritative action can hardly go; for it must depend, not alone on the poison, but also on the capacity of irritability possessed by the living structure; and this, although it is capable of being renewed, or spurred by extraneous influences, when flagging, is plainly a very exhaustible quantity.

From the third characteristic a little consideration will enable us to anticipate results, which will in part be the direct opposite of those of the second; and, if we reflect that the actions of the second are maintainable only so long as, and according as, the capacity of irritability remains to the living organism, whereas those of the third depend on no potency in the animal structure but only on the unvarying property of the poison to extinguish oxidation, we shall see good reason for attributing to those of the third a more prevailing permanence, and even the power to counteract and control in less or more degree the others. The extinction, in a degree small or extensive in proportion to the comparative amount of free carbonic acid in action, of the natural oxidation or combustion of tissue, which is ever going on in the living body and on which the procedure of living depends, will certainly more or less markedly affect the execution of living function in, and both the constitution and the temperature of, the living structure. It will diminish and retard the execution of all the functions of each part and structure. It will hinder the healthy changes of tissue which the execu-

tion of function always entails and which are necessary to the continued life of the part, and probably those changes also which have been attributed to the irritation of the acid quality of the poison; while at the same time it will add in another way to the tissue-waste by causing, according to its degree, the organic death of a greater proportion of the ultimate constituents of the tissue. It will also seriously affect the function of the voidance of waste products, will bring it about that these shall be in some measure retained in the substance of the tissues that begat them, and by their retention will cause these tissues to become slowly, but seriously, altered in character and constitution; or, crippling the self-renewing energy of the tissue, it will tend to prevent the tissue from being renewed in its own quality and to cause it to be gradually replaced by one of a lower form of organization.

Further, the arrest or limitation of the natural combustion of the tissues must have a continual and necessary tendency to lower the body heat, both directly from its own nature and the inter-dependence of the two conditions, and indirectly from its having also lessened the activity of the natural resident functions. It will thus be, that, in relation to the temperature of the body, the second and third characteristic will act in opposite directions and antagonistically; while the second elevates the body-heat, the third depresses it; and without doubt, *ceteris paribus*, the third will in the long run prevail over the second. But it will be within the influence of extraneous circumstances to mediate in this antagonism, and to incline the victory temporarily towards the one or the other, as thus;—such circumstances as external warmth, from warm quarters, warm clothing, heat of noon-day sun, &c., or internal warmth from muscular exercise or mental interest, hot viands and drinks, excited emotion, &c., would tend to

favour the heating influence of the irritation of the second characteristic; while such, as external cold from exposure to the chill of evening, night or morning, wet weather, cold winds, wet habiliments, &c., or internal cold from inanition, exhaustion from fatigue, anxiety, disappointment, depressing emotion, &c., would favour the chilling, deadening effect of the third characteristic. And the alternations of these extraneous circumstances would in return be often, perhaps distressingly, accentuated to the sufferer by these two alternately prevailing characteristics; while, as before indicated, the whole conditions would tend gradually more and more to the prevalence of the chilling and depressing influences; and the temperature of the body would acquire a mean temperature below what is normal in early life.

It is difficult, in speaking of these consequences of the very slow and gradual accumulation by very small, but continual, additions of carbonic acid in the system in the long series of years from childhood to extreme age, to use language sufficiently attenuated to represent with any real accuracy the slowness, and yet the extent, of the change of condition of the body that is produced. Making this allowance then for the somewhat condensed language that I have found it convenient to employ, it has been shown—that probably from the beginning to the end of human life there is a continual, slow, and comparatively small accumulation going on of free carbonic acid in the body—and that the essential properties of carbonic acid in relation to animal organic life and function necessarily entail certain actions with observable and important consequences to the animal condition, which have been generally indicated. But to show these more positively, it will be of service to follow them into somewhat closer detail and refer to definite instances. Taking, then, the general principles indi-

eated above and applying them to particular tissues and organs, let us endeavour to ascertain what are the apparent changes, that would occur from youth to age in the appearance and condition of the body; and see if these correspond with the actual experience of human life.

One of the first things to attract admiring notice in the person of a very young child is the delicacy of the skin, both as to its texture and its colouring. But during advancing years this delicate skin will be subjected, as has been described, to the slowly progressive action of carbonic acid;—the active vitality of its organic nature will be lessened; the natural processes of wear and repair of tissue will be impaired in activity and altered in character, the natural waste being increased by the acid irritation or diminished by the arrest of oxidation and some elements of tissue being devitalized *in situ* and preserved there lifelessly by the antiseptic power of the poison; the natural powers of voidance of waste material will be weakened and some proportion of this being retained will thicken the substance of the skin, alter its pristine delicate tint to a paler, deader hue, tend to lower its natural temperature, and greatly deprive it of its appearance of life-like tone. The appendages of the skin, also, the hair and the nails, will in their measure share in specifically the same series of transformations.

The areolar tissue will be subject to like effects; the faults of waste and elimination and repair will be the same, with these consequences—that, as the fat which is enmeshed in it becomes borne off and used up in the economy of the body, it will be replaced less and less by pure fat, but will have particles of debris of the areolar tissue mixed with it in ever-increasing proportion; while the tissue itself will be thickened in the way that has been described as to the skin; and eventually the so-

called fat of the body, the material whose office it is to cushion all its structures, will not only be less in quantity, but also be of a constitution far removed from that of the fat of childhood. The condensed areolar tissue, that forms the casings of the internal organs and supports their several intimate parts and their relations, will undergo the same processes; in the liver it will thicken and solidify between the lobes and lobules and will impede both the circulation and the glandular function; in other organs, as the pancreas, spleen, kidneys, supra-renal capsules, prostate, &c., it will grow and become obstructive in the same way, subject in each case to circumstances peculiar to the individual organ; while in the intestines, besides that the functions of the intestinal glands will be impeded partly by this condition and partly by the direct deadening action of the carbonic acid, it will impair also the power of their muscular action, prevent the due propulsion of their contents, and produce habitual constipation. And other situations there are, as the cornea or even the crystalline lens, where the areolar tissue is of a very dense and fine nature, where the red corpuscles of the blood do not freely circulate, and where hardly any element productive of opacity is naturally to be found; in which it might be possible actually to see these results occurring, a growing deposit in the substance of the tissue of an opaque material, the deposit following the form of the structure or corresponding with the adjacent boundary of an area of freer blood circulation. From the nature and relations of the function of the lungs it may be expected that the lung tissue will be subject to the same progressive changes as have been described in relation to skin and areolar tissue in general; it will become more dense, less elastic, less instinct with its original power of vitality, more resistant to the free course of circulation

and respiration, and aeration, and so will tend to induce ineapacity and shortness of breathing, which will be capable of being observed in the experience of the individual and by him regretfully contrasted with the free expansive capabilities of his lungs in early life.

In the heart by the same processes, although, one side of it being by nature designed and equipped for dealing with blood laden with carbonic acid, and the other side being continually and revivingly engaged with the reception and conveyance of fresh oxygenation to the system, it will be in some measure fortified against them, the muscular structure will become hampered by a retained proportion of debris of defunct tissue, partially devitalized in its muscular fibre, and affected perhaps in some degree on the right side directly by the carbonic acid; probably manifesting during life some symptoms of its condition by its action being weak, unsteady and excitable; and revealing after death such conditions as paleness, flabbiness, and friability of texture.

But, additionally—weakness of action and a susceptibility to small excitement would be induced in the heart—as would weakness and ineffectiveness in the muscular system in general, and irregularity in varied degree in the functions of internal organs—by the conditions of the nervous system; whose tissue would in its degree partake in the degenerating processes, that have been described as to other tissues,—besides being weakened functionally by continued irritation of the carbonic acid; and whose highest expansion, the brain, would probably give signs, in dulness of perception, slowness or inefficiency of mental process, inconclusiveness, weakness of will power, susceptibility to disastrous emotion, ready exhaustion, &c., that the freshness of life and stimulus, which once belonged to it, is gone for ever.

Now, these conditions,—which I have imperfectly described and attribute, as necessary results, to the action of the certified properties in relation to animal life of carbonic acid, ever present, gradually and slowly but surely accumulating in the body, and warring against it from infancy to the end of life,—are the conditions of advancing age common to human experience; and, tracing, in accordance with principles based on our ascertained knowledge of its essential and unchangeable properties, the natural consequences in the body of the assault of carbonic acid carried on through a succession of many years, I find myself describing phenomena, which, leaving aside distinctly recognised forms of disease, are the characteristic phenomena of the progress and decadence of natural human life. This being so;—the conditions, which have been described imperfectly above, being the characteristic conditions that mark advancing age as compared with the early period of human life;—these conditions being such as it has been shown that carbonic acid can and must produce;—it being the fact also that from our birth until our death we are surrounded by, and open to the continued attack of, carbonic acid, and that it is the most constantly present of all the constituents of our environment, not excepting perhaps even aqueous vapour;—it seems but reasonable to say conclusively, that it is the carbonic acid of our environment that is the cause of the changing conditions, apart from incidental diseases, which make the physical condition of the body in extreme age to be so different from what it was in pristine childhood. Further it may be said, that, the progress of this change being always in the direction of deterioration and decadence, carbonic acid is a factor which would—and does—tend ever to the wearing out and smothering of the vital principle, to the progressive molecular death of the body, causing man, apart from any

effect of so-called disease, to be, really and always, what he is often pathetically termed, a dying creature,—not “*moriturus*” only, but “*moriens*”; and that, were none of the many recognized and named diseases to assail us, still our lives would have bounds set to them by the prevailing hostile power of carbonic acid, which is ever bringing death in part to us little by little every day and hour we live from infancy to the grave.

SECTION III.—These are the effects of a natural slow and comparatively small accumulation of carbonic acid in the system, caused by a certain degree of natural inadequacy or incompleteness constantly qualifying the functions provided in the body for voiding it, progressing gradually and persistently from the beginning to the end of independent life, yet never advancing to that degree of disorder which could of itself be reckoned a “disease.” But the amount of carbonic acid introduced into, or imparted to, the system and hurtfully retained therein may be abnormally increased from several very conceivable sources; the consequences of which increase on health it will be of interest to consider carefully. Sources of an increase in the amount of carbonic acid remaining in the system may be looked for—

1. in anything that tends to restrict still further the adequacy or efficiency of the natural discharge of it from the body;—
2. in anything that tends to increase the formation of it in the body;—
3. in the presence, from extraneous causes, of a more than normal quantity of it in the atmosphere in which the lungs exert their functions, or in the supply of water which is used for drinking.

Instancing the first of these classes, the use of such drugs as opium, ipecacuanha, antimony, &c., may be re-

ferred to. Opium, in diminishing the frequency of the heart-beat and of the respiration, retards without doubt the natural functions concerned chiefly in the elimination and discharge of carbonic acid; and, among the apparent consequences of long-continued vicious use of this drug, there may be plainly recognized, in an extreme degree, conditions which have been described above as capable of being produced by the prolonged action of carbonic acid and which it is hardly necessary here to particularize again. Ipecacuanha diminishes the force and frequency of the action of both heart and lungs, and has the same retarding effect on the voidance of carbonic acid; but it is not an article that is indulged in for pleasure and we have no such recorded experience of the effects of long-continued or excessive use of it, as in the case of opium. Antimony depresses the functions of circulation and respiration, and to it the same effect is attributable, of lessening the elimination of carbonic acid by their means. Ringer says, that under the influence of antimony carbonic acid is eliminated in greatly increased quantity; but he goes on to say, that whether the medicine is to be considered a mere eliminator or whether it likewise increases the formation of carbonic acid his experiments were not continued long enough to decide; while I gather, from his associating carbonic acid and urea together in his statement, that the elimination to which he refers is only that which is effected through the kidneys; and I certainly incline to the idea, that the increase of this elimination which he observed under the influence of antimony was due to, and complementary of, a diminished elimination due to the same influence through the more natural means provided for it in the lungs. Again there is yet another available means for the elimination of carbonic acid—by the excretory apparatus of the skin; the efficiency or measure of which it

would be difficult to estimate ; and I am not aware that any means of accurate estimation has been applied to it. But it is a striking fact, that each one of these three drugs which I have named, as illustrative examples of factors capable of diminishing the discharge of carbonic acid through the lungs, is noted for—and is employed in the treatment of disease in recognition of—a marked influence which it possesses to increase largely the excretion—the elimination of something—by the skin. Nor is it absurd to think, however difficult it may be to prove, that the excretory apparatus of the skin, in some compensation for inadequacy of effect in the function carried on in the lungs, may be endowed with a faculty of discharging in the vehicle of moisture some quantity of carbonic acid, may be capable of being stung by the presence of the acid to an excited action of secretion whereby some of it would be eliminated. This, partly perhaps vicarious, office in the skin seems as likely as in the kidneys. And this idea, as regards the skin, receives indirect support from a contemplation of the effects of the administration of another and different medicine, belladonna ; which, while—or because—it increases the frequency of the play of heart and lungs and thereby also hastens and promotes the discharge by them of carbonic acid, at the same time greatly lessens or altogether arrests—or allows to become quiescent—the secretion of the skin. A connection, it would seem, does subsist, of some sort, between the fact of free carbonic acid being present, in some intolerable quantity, in the general tissues of the body and the phenomenon of more or less profuse perspiration ; the later surely being the consequence and the former the exciting cause. It is not mentioned by Taylor, that much moisture of the skin had been observed in the fatal cases of carbonic acid poisoning to which he refers ;

but it is a condition that would very easily and naturally pass without attentive observation and record; and he does mention one post-mortem condition, that of the presence of an abnormal quantity of serous fluid in the ventricles of the brain, which I think is to be looked upon as an allied phenomenon, attributable to the same sort of transudation of carbonic-acid-bearing fluid through the serous membrane, as that just contemplated in the skin; as, also, I think the increased secretion from the mucous surfaces, which ipecacuanha produces, is probably due to a similar immediate cause.

Regarding the second class, of causes that would operate to increase the amount of the carbonic acid by promoting, or affording means for, an additional generation of it within the body, it is evident that this additional generation may arise, either from an increased combustion of tissues belonging to the body, or from a greater amount of new material for combustion being supplied by the consumption of certain articles of food or drink. An instance of the former of these is to be found in any extraordinary muscular exertion, the active excitement of which occasions a more rapid and general combustion in all the tissues affected by it, and produces from their oxidation an extraordinary formation of carbonic acid. The slight duskiness of colour appearing in the countenance after a short continuance of such exertion will betray a certain degree of that turgidity of the capillary and venous systems which was evidenced by appearances remaining after death in Taylor's fatal cases; and early in the time of the exertion sweating will occur, having relation to, and bearing witness of, carbonic acid present in unusual quantity, as pointed out in the preceding paragraph; while the circulatory and respiratory apparatus will be found to display an activity far beyond their ordinary rate, which

will be maintained for some little while after the general exertion has ceased in order to achieve the task, that falls chiefly to them, of eliminating the increased quantity of carbonic acid; the unusual activity of the respiratory apparatus and the profuse transudation by the skin, together, in a short time effecting, in a healthy subject, a nearly normal riddance of the acid and then, together, gradually subsiding. It may be objected that the perspiration is due to the impetuous force of the circulation; but, if an impetuous circulation be the cause of such a result, how is it that a quite opposite condition of the circulation, produced by *ippecacuanha*, is followed by the same result. I attribute the sweating to a specific incitement by the carbonic acid; it being one of the ordinary waste products of the body, in the natural elimination of which, incited by the simple intolerance of its too abundant presence, the skin is ordained to take part. Instances of other sources of the additional generation of carbonic acid within the body are found in certain articles, which are taken into the digestive system as food or drink or drug; which, possessing carbon as an element of their own chemical composition, afford material for the formation of carbonic acid in the oxidation and transformation which they undergo in the body. There is no need to enumerate these particularly; it is enough to say, that they are various and that they display a varied degree of facility in giving up their carbon to this special end; and it will be sufficiently illustrative of the effects of such sources of carbonic acid, if I refer at some length to one of them,—alcohol,—whose facility of conversion in the system in great part into carbonic acid I believe is indisputable, and whose effects both on apparent health and on the structures of the body have been extensively explored and recorded.

It is obvious that, some of the effects of alcohol, which

have thus been reeorded, are due to the action on the living functions of the still uneconverted alcohol; and with these, it is hardly needful to say, my subject has no concern. But there are other effects, mostly arising or becoming more marked as aleoholie disease advances, which can only be reasonably attributed to retention and accumulation in the body of products of the conversion of the aleohol; and these have close eonnection with my subject. The direct effects of an excessive quantity of alcohol, while it is still supposed to exist in, and act on, the system as aleohol, may be shortly referred to as exaltation and lethargy, the former subsiding and merging into the latter, and both being renewable frequently, from time to time, during a long habit of vicious indulgence; coincidently, however, with such repetitions, there are developed other manifestations, which are diverse from the accredited direct effects of aleohol, but which are in remarkable agreement with the effects of carbonic acid,—and even the lethargy that forms the second stage of what is regarded as acute alcoholism, I think, marks a period when an important quantity of the alcohol that has been taken is already converted into that final product. Characteristic features of this lethargy are—sensation of weight in the head—giddiness—great loss of muscular power—strong tendency to sleep—eventual subjection to deep sleep in which sensibility is quite lost and the breathing is difficult and stertorous—warmth of body—limbs very flexible—sometimes irritability of stomach and vomiting—and, for some time after resuscitation, pain in the head, with pain and soreness over the whole body, &c.; a series than which a nearer parallel to the train of symptoms of carbonic acid poisoning described by Taylor could hardly be found. In the more advanced manifestations and pathological changes, which have been met with after the aleoholie poisoning

has continued and become chronic, there are, I think, still further evidences and illustrations of the actions and effects of carbonic acid:—

in the inquietude of tissue, that besets the whole system, said to be one of the earliest symptoms complained of in chronic alcoholism; which produces such restlessness as to prevent almost entirely the subsidence into sleep at night; develops later into a persistent muscular tremor, at first somewhat restrainable by a strenuous effort of will-power, but soon getting quite beyond such control; further goes on to more central nervous manifestations, as *muscæ volitantes*, vertigo, insomnia modified only by short snatches of sleep with disturbing dreams, to an abiding excitability of temper and emotion, inconsecutiveness of purpose, fearfulness, delusions, &c.; and which is locally evidenced also in the stomach by frequent vomitings, sometimes sudden and sometimes when there are no ingesta in the viscus which could cause such an occurrence;—of all which the cause lies in the perpetual and accumulating presence in all the tissues—appreciated most prominently as affecting the nervous, because on it so specially do the functions of the others depend, and because any derangement of it so speedily attracts attention,—of the irritating acid obnoxiousness of the poison, the manner and consequences of which have already been spoken of:—also, in the increased exudation from the skin, ranging in degree from the clammy moisture which is a habitual condition of advanced chronic alcoholism to the profuse sweating which occurs in alcoholic sleep and in delirium tremens; which I have already pointed out as apparently a specific result of the presence of an intolerable amount of carbonic acid, and which may be held to illustrate both the irritative excitement produced by it and its remarkable diffusibility, by virtue of which the skin is reached by it

and caused to take a more equal part with the lungs and kidneys in its extrusion :—

next, in the loss of muscular power, languor, inability and consequent reluctance to make an effort of even a trifling nature, impaired tonicity and power of the bowels to carry forward their contents to defæcation, restricted capacity of respiration ; sluggishness of mind, loss of power of intelligent sympathy, a permanent condition of apathy blending with and transcending a habitual selfish discontent, and dull ineffectiveness of body and of mind ; a temperature which, however fitfully it may vary in early stages of the alcoholic habit with the occasional rise and fall of the irritation of the poison, is always, except when some complication of an acute nature supervenes, persistently low when the alcoholism has become a habit of long-standing ;—these being phenomena of chronic alcoholism, which have received less special notice from professional observers, I think, than is due to them, but are quite discernible, even in not very advanced cases, in the intervals of acute irritation,—which intervals occur in all cases and must occur occasionally if the exhaustion which the irritation must produce is not to proceed to dire extremity,—and form the mainly prevailing condition of many cases of very advanced habitual toppers ; all of them being due to the overwhelming power on the vitality of tissue and function, which has been pointed out before to be the consequence of the essential character belonging to carbonic acid, of preventing the necessary vitalizing oxygenation of blood and tissue, and, as also pointed out, is sure eventually, in the long run, to overcome even the irritation caused by the same poison, which must in some degree depend for its continuance on the continuance of a relative degree of vital excitability :—

again, in certain pathological changes—in an infiltration

and invasion of the proper substance of the lungs by a mass of unremoved material of tissue waste, rendered antiseptic and unremovable by the carbonic acid, which has replaced some and hampers the remainder of the normal lung tissue and, in conjunction with a degeneration of the same kind in the muscular fibres of the air tubes, is the cause of the restricted power and capacity of respiration; — in changes in the constitution of the brain, &c., in which “the true elements of nervous tissue are partially removed, the total mass of nervous matter wastes, while simultaneously there is a marked development of fibrous tissue, granular fat, and other elements which belong to a low order of vitalized products,” changes which represent an essentially similar result, produced by the same process of degeneration as that in the lungs;—

in a thickened, increased and apparently sodden condition of the skin and cellular tissue, from the same process, displaying in life an unwholesome pallor; relieved sometimes and in some situations, as cheeks and nose, by a bluish hue of retarded and badly oxygenated capillary circulation;—

in the “serous fluid effused into the ventricles and the arachnoid,” due to the same condition of the capillary circulation and a specific excitation of the serous secretion by the permeating carbonic acid;—

in “degenerative change in the structure of the submucous tissues, which consists in the disappearance of characteristic secreting structures, and the hypertrophic exaggeration of fibrous tissue,” consequent on the same processes as held place in the lungs, brain, &c., and causing in the bowels the condition, in which is displayed the inefficacy of function, the passive constipation, already alluded to;— in the stomach similar infiltration and degeneration of its normal tissues, with capillary circulation imperfectly

oxygenated and retarded and distended, and with glands occluded or injured and vitiated in their secretions;—similar and similarly produced changes of tissue and interference with function in the liver;—similar results in the kidneys, producing Bright's disease, &c.;—and lesions of the same order, giving less serious disturbance during life, in other organs;—

the cause of all these being referable to the combined exercise of the two main characteristics of the action of carbonic acid on living animal structures, after the manner that has already, previously, been insisted on,—the intimate interstitial irritation of the acidity of the poison effecting a certain increase in the amount of exhausted and effete tissue-material; and the deadening of tissue and of function, by the prevention of necessary oxidation, by the carbonic acid, paralysing the natural excretion of such effete matter; thus conserving, in *loco quo*, a quantity of partially or wholly devitalized, carbonic-acid-laden, antiseptic material, of varying nature and degree of solidity or moisture according to the varying character of structure in varying situations.

All these symptoms and conditions, then, arise naturally and explainably from the accumulation, in and throughout the body, of carbonic acid, the very diffusible and injurious product of the conversion in the processes of the system of alcohol, which has been habitually indulged in for a long time. And in reference to this conversion, it is relevant to adduce a fact, that seems to indicate how speedy it may sometimes be. It is not an uncommon thing, for a glass of spirits to be taken just before bedtime with the express purpose of procuring a good night's sleep,—sometimes the imbiber will declare that he has no chance of a good night unless he takes it;—then, perhaps he does fall asleep the sooner, perhaps the more

certainly, for it, the stage of lethargy supervening the sooner for the seclusion, darkness, and other conditions of repose into which he has betaken himself;—but this sleep soon ends, and the sleeper after a heavy slumber of two or three hours is no longer asleep, nor sleepy, but awake, and wakeful, and unable to get to sleep again:—a termination which I attribute to the alcohol having been, in great part at least, converted in the system during even that short space of time into a tissue-irritating quantity of carbonic acid. It has indeed been held by some that such a conversion does not occur at all; but “notwithstanding,” writes Anstie, from whom I have already quoted, “all that has been urged in favour of the view that alcohol is not transformed within the body, the balance of evidence is strongly in favour of the belief that a considerable portion of every dose of alcohol which is ingested does undergo oxidation in the system, and that to the diversion from its ordinary purposes of the inspired oxygen must be ascribed the diminished activity of elimination of carbonic acid, of urea, of chlorine, and of the acids and bases of the urine, which undoubtedly does occur in the subjects of alcoholic poisoning”:—to which I would add, that,—besides the diversion of the inspired oxygen and the consequences therefrom that he instances,—the product of that diversion, carbonic acid, being endowed with an intrinsic power of preventing further oxidation in its presence, whatever oxygen be supplied, is thereby capable of, and assuredly exercises the capability, of stopping or retarding the elimination of more elements of the waste of organic tissue than he has enumerated,—and not so much definite final products of tissue-oxidation, but matters still retaining much of the form and nature of the original organic structures by reason of the want of that oxidation which is required for their reduction; and that thus it causes

these to be retained in the tissues, filling them up interstitially with a pseudo-organic, antiseptic material, which serves as a bed for the permanent entertainment of accumulating accretions of carbonic acid, hampering life and function, replacing in part the normal structures, and constituting degenerations of tissue in all parts, of a character circumstantially varying, yet essentially identical, everywhere:—as in the foregoing I have endeavoured to show.

The third class, indicated above, of sources of carbonic acid which should invade and seriously injure the healthful active powers of the system, the manner and consequences of whose invasion will now engage inquiry, includes—a local atmosphere laden heavily with carbonic acid, which it carries into the lungs in every intake of respiration—and a local water-supply containing much carbonic acid in solution, which is borne into the stomach in every draught of the water. The two sources are almost always found co-existing in the same locality and affording the same poison to the dwellers there simultaneously;—although the amount of carbonic acid drawn into the system from the atmosphere will no doubt be far greater than that derived from the water, because the process of respiration has to go on unceasingly, while drinking could only be an occasional act, and notwithstanding that the relative quantity of carbonic acid dissolved in the water may be much greater than the proportion of it to be found in the air;—and the difference between the two modes of administration of the poison cannot be supposed to cause any eventual difference in the injurious results, but only to be an initial variation of but theoretical importance. The offensive action, then, of the carbonic acid inhaled, from an atmosphere charged with perhaps three or four times the amount of it ordinarily to be found in the common air, will probably first attain any serious signifi-

cence in the capillary circulation in the lungs;—where the blood, which arrives there in the expectation of having its vital availability and worth renewed, by the discharge of some quantity of carbonic acid which it has brought from the systemic circulation, and especially by a fresh access of oxidation from the inspired air, will fail of this renewal, —because the carbonic acid with which the inspired air is already too heavily laden possesses, and exercises, there or anywhere, to a degree relative to the proportion in which it is present, the hostile power of preventing the process of oxidation, while probably the same hostile power will diminish in some degree the energy of the air-vessels in their discharge of their previous burden of the same offensive product. That, again, which is received by the stomach in the medium of drinking water, will there be chiefly taken up by vessels of absorption or circulation and borne away in their fluid contents to the heart and onward to the capillaries of the lungs;—where it will be added to the larger quantity that has been brought in by the air-vessels, and will intensify, in the degree of its relative amount, the consequences indicated above. But, besides the main destination of the carbonic acid from both these sources to the blood, a small portion of it in either case will be, through the medium of the degree of moisture belonging to the constitution of organic tissues, communicated, not without some effect on them, to the general textures which lie contiguous to the avenues of its reception and convection.

The carbonic acid, then, from either source, having its first principal focus of action in the capillaries of the lungs and there acting as a preventive of the natural and necessary oxidation of the blood,—the flow of the blood through the capillaries will be retarded, primarily from the want of natural stimulus in the fluid itself, partly perhaps from

a lowered tone in the walls of the capillaries; and the dependence of their current on the action of the heart and larger vessels would be increased:—also, the temperature of the substance of the lungs, as well as of the blood, will lose, in the diminution of the oxidation, part of its chief maintaining condition; were it possible to ascertain the internal local temperature of the lungs, it would be found to be appreciably lower than its wont; and, as far as the sensibility of the innervation of the lungs is capable of indicating and observation is directed thereto, there will be a deep-seated sensation in the chest of unusual cold. Thence the blood, deficient in oxygen and too abundant in carbonic acid, being returned to the heart and by it sent on to the supply of the body in general, the next stage in its course, where early effects of the carbonic acid are to be looked for, will be in its passage through the capillaries of the systemic circulation; where the extreme delicacy of the blood vessels and the extreme sub-division of the current of the blood conduce to an extremity of intimacy in the relation of the blood to all the structures which it is its office to nourish; and where the vitiation of the blood by the carbonic acid is destined to receive an additional strength from the taking in of more carbonic acid, the product of antecedent oxidation in the surrounding textures. In these capillaries,—in all parts of the body,—whether underlying dermal or mucous or serous surfaces,—or ramifying abundantly in the substance of massive tissues,—the same altered conditions of function will occur, as in the capillaries in the lungs:—there will be a similar slower movement of the current of the blood; a diminution of the interchange between blood and tissue of nourishment imparted and impurity carried away; and a lowering of the natural temperature of both blood and tissue,—recognition of which by the nerves of sensation

will be very probable as regards external surface, and may happen also as regards body-tissues in some degree, according perhaps to the degree of intelligent observation that is consciously exercised by the mind,—but which, in some situations, may be verifiable with a thermometer. But the temperature will be interruptedly disturbed, will now and then be temporarily raised, and the natural process of exhaustion and waste of tissue will be hastened and exaggerated, as I have pointed out before, by the irritation of the intimate presence in the substance of all tissues of an obnoxious agent of acid quality like carbonic acid. And in the long course of time as a result of the combined, though in some ways of opposing, working—of this irritation, varying in degree from time to time according to the favouring or subduing influence on it of sundry contemporaneous extraneous circumstances to which I must refer more particularly by and bye,—and of that more prevailing and less variable property of the carbonic acid, of preventing oxidation and thereby of paralysing more or less the function of eliminating the products of tissue-waste, while in its own devitalizing way it adds to the extent of ineffectiveness and effecteness of the constituents of tissue,—the structures of the body will all, in degrees according to their varying conditions of laxness and softness of texture, of freedom of blood-supply, of situation and of function, become denser, bulkier and changed in constitution, in ways which I have already attempted to indicate. It is hardly needful to observe, that in forecasting consequences one must endeavour to take into account, as far as may be, each different mode or source of action or modification.

In the skin, the condition of the circumferential circulation will be made more or less evident by pallor or duski-ness of hue replacing the warmer colour that is afforded

by a well-renewed arterial blood ; and, along with this, will begin to appear an abnormal, almost constant and apparently passive increased sudorous exudation, a perspiration unaccompanied by heat and unassociated with activity, such as I have already noticed in connection with carbonic acid and have attributed to a specific action of the widely diffused poison involving the skin with other organs in a general effort to extrude it from the system ; symptoms referable to the irritative quality of the poison will also present themselves,—at times perhaps the skin will be found to be hot, sharing in a general elevation of temperature of the whole body from concomitant circumstances tending to foster the irritation ; but more often it will be found to be cooler than it should be, partly owing to the subjugation of irritation, as well as of natural vital heat-generating process, by the more steady and prevailing devitalizing property of carbonic acid, and partly owing to evaporation of the exuded moisture,—sometimes the perspiration may be accompanied with considerable pain of a distressing pungency from congestion and tenderness of the sudoriferous follicles, which might also be evidenced by minute red puncta over the skin and would be liable to be sharply aggravated on a sudden fillip of any kind being communicated to the circulation, or sudden movement of, or contact applied to, the integument,—the superficial exuviation of epidermis will probably be notably increased and may be observable in the process of drying the skin with a rough towel,—and after long years the results will become apparent, in the changed nature of the skin, of the combined effects of the irritating and the devitalizing properties of the poison, of which I have spoken ; it will take on a visibly leathery character, have a pale and dead like colour, and recognisably be thicker, denser and less pliable ; the subdermal

cellular tissue will have undergone simultaneously the same process, and will partake of the same thickened and degenerate condition; and the appearances will be realized, and the underlying characters also, that have been described under the appellation of Myxœdema.

The mucous surfaces will be affected in a perfectly analogous manner, according to their nature and situation:—the same unhealthy pallor, as in the skin, will be observable in the buccal and pharyngeal mucous membrane, with perhaps a mottled appearance or “patches of violet hue,” similar in nature and cause to those described by Taylor on the cutaneous surface of fatal cases of carbonic acid poisoning;—as regards temperature, the mucous membranes cannot well be dissociated from the subjacent textures, which will partake in the general temperature, for better or worse, of the whole system;—the secretion of mucus will be increased, and at the same time so also will be the exuviation of epithelium; the secretion on the mucous surface will thus not be pure mucus, but a composite, thickened with epithelial debris, more bulky and viscid and tenacious, and causing more or less of difficulty and hindrance to whatever function or process may depend in any measure on the free and easy lubrication of the surface, with varying consequences in varying situations,—on the naso-pharyngeal mucous membrane this secretion, further inspissated by the drying effect of the comparatively free access and passage of air, will clog the posterior nares and pharynx to the discomfort of those parts and their neighbourhood,—in the respiratory passages the secretion will be more or less effectively prevented from collecting in obstructive quantity by the onward vibration of the cilia of the ciliated epithelium lining these passages, but it will frequently cling at the upper part of the larynx and after a reposeful night may

often be found to have collected in considerable quantity in larynx and pharynx, and eventually, in course of time, some of the terminal air-cells, here and there, progressively, will become occluded, so as, in conjunction with subjacent conditions, to restrict the respiratory capacity of the lungs—in the œsophagus the secretion will be viscid and foul, mucus thickened with epithelial debris and tainted with ingesta causing a very disordered condition of the part—this secretion will be carried down into the stomach and added to a much larger amount of the same kind secreted abundantly there, which will materially interfere with the due admixture of the gastric juice with the ingesta, will hamper in some degree by its clinging viscidly the movements of the stomach-walls on their contents, and will give rise to various hindrances and irregularities of digestion, ere the chyme laden with impurity is passed into the intestine—it will also be secreted in the whole length of the intestinal canal and form a sticky slimy covering to it, which its contents will catch up and carry away with them, accumulating, as they pass along; which will make their passage slower, increasingly as they approach the termination, will elude both absorption and secretion, vitiating the secretions of the intestinal glands and perhaps eventually occluding them, or some of them, altogether, and will, in concert with subjacent conditions, tend to habitual constipation of a persistent and troublesome character:—and on other mucous membranes the carbonic acid will cause a like increased and thickened secretion, in varying abundance and with varying facility of removal, which will in some way be prejudicial to their welfare and their function, as in glandular ducts, the bladder, the womb, &c.; but the great respiratory and digestive surfaces will suffice for present detail;—lastly, after a much prolonged subjection to the presence

of carbonic acid, the same characters of alteration will be found in the general texture of the mucous membranes, as have been described in the skin; they will appear blanched in colour, will be thicker and denser in their whole texture, and less delicately qualified for their positions and uses.

The serous and synovial membranes will be affected analogously with the skin and mucous membranes, though the consequences will necessarily not always be so open to demonstration or even deduction, nor will they, unless in rare exceptional cases, be likely to have any such extended bearing on the general welfare;—all surfaces, indeed, from the nature and necessities of their position, bounding, deflecting and turning back the channels of the circulation, must receive, as in a bending river the outward bank will do, an impetus therefrom unknown to other parts of less defined limitation, which will show itself in results on the surfaces in extravasations and in temperature;—on the serous membranes the secretion will probably be increased and will constitute there a chronic form of what in the ventricles of the brain in Taylor's fatal cases may be said to have been acute, the capillary circulation there being chronically in a sluggish and distended condition; while the temperature will probably vary, along with that of the general structures, according to the occasional and temporary predominance of the irritating or the devitalizing action of the carbonic acid, dependent on circumstances beyond the limits of the part;—in the synovial membranes similar conditions will occur, while the temperature by reason of the slenderness of substance intervening between most of them and the external surface will be affected by one specially of those influences which make for depression and will prevalingly be low; and some of the observable

consequences will probably be such conditions as are commonly described under the name of Rheumatoid Arthritis.

In the substance of the general tissues, the massive structures and special organs of the body, the actions, which have now been so often referred to, of Carbonic Acid on living and active organic tissue will be abundantly exemplified, at one time the irritative and at another the devitalizing action having predominance over the other, but each maintaining the continuance of its own influence in some degree at all times; and the results in these will be in their essential nature the same as have been pointed out in the cases of the surfaces, but will be subject to modifications of actual effects, both in the degree and in the mode of their operation, according to the nature and activity of particular structures—as, for instance, the cellular, fibrous, muscular and nerve tissues, the liver, kidneys, spleen, supra-renal capsules, thyroid, prostate, &c. Keeping in mind the extreme diffusibility of the poison and its ready convection to all parts of the system, it may naturally be expected that some of its actions, simultaneously comprehending all the regions of the body, will give rise to symptoms which will have a general character, affecting the whole constitution at the same time. This seems particularly likely to be true in regard to body temperature; which, as well as the poison affecting it, is of a peculiarly communicable and diffusive disposition:—the irritative quality of the carbonic acid, exasperating the functional activity of every tissue, and prominently that of the nerves, will always have the tendency to increase the tissue-heat and, acting generally, to raise the temperature of the whole body; the devitalizing power on the other hand, preventing the oxidation or combustion of tissue and depressing every organic

process of life, will as invariably prevent the maintenance of the heat otherwise maintainable in the tissues and lower the body-temperature; while the predominance of the effect of either of these contending actions over that of the other will vary and will be largely determined by the coincidence of extraneous ruling conditions, acting in the body or in its sensible environment.

Such ruling conditions are to be found in the many varying circumstances of ordinary existence, which have power to influence in the body, for good or evil, the vigour, with which its functions are carried on :—
the irritative action of the carbonic acid, which, as before pointed out, must depend in some degree on the amount of the existent vitality of tissue capable of receiving irritation, will be promoted, and the body-heat coincidently advanced, by a liberal use of such ingesta as are possessed of a considerable degree of warmth, either the warmth of temperature or of pungency, and containing a preponderating proportion of fluid, which is more easily absorbed and is of service in dispensing the nourishment with greater celerity to the system at large; also by alcoholic stimulants, especially if taken hot, but these will finally, having been converted in the system into additional carbonic acid, lend themselves to the opposite side ;
while the devitalizing and lowering action will be favoured by insufficiency of food or the use of cold and solid viands, which do not impart heat of themselves and, instead of affording any stimulus through a speedily increased volume of the circulating fluid, act as local derivatives in the stomach, whose secretions they tax, and tend rather to abstract both vigour and heat from the general system :—
again, the irritative action and its effect on the temperature will be aided by any healthy exercise, in which the activity of the circulation and of the faculties in general is

promoted,—by exercise of the bodily powers, such as does not however extend, either in point of severity or in point of duration, beyond the easy capacity of those powers,—by vigorous exercise of the mental powers, with the same limitation,—and by the exercises of lively imagination and of pleasurable or violent emotion, more particularly in individuals of much nervous sensibility or excitability ;

but bodily exertion carried on to fatigue or beyond that extent to which the existing powers of the body are fully equal, especially if followed by deprivation or neglect of the opportunity and means of recuperation, will inevitably tend to place the devitalizing and lowering property of the poison in the ascendant,—and so also will severe and harassing or long-continued labour of the mind, and grievous or depressing emotion, and any lengthened endurance of such a repression of energy as that involved in waiting :—

again, the irritative action, including and followed by all those consequences which have been attributed to it, of local, interstitial, vicious stimulation of tissue-function, which tends to raise the temperature, will be promoted and intensified by the effective use of any of those artificial appliances whose object is to maintain the comfort, vigour, and natural sensibility of the body,—by warm and protective clothing,—sufficient means of warmth and rest in sleep,—shelter of good, dry and sound housing,—and all those means and circumstances which tend to the protection of the surface of the body primarily, of the whole bodily economy consequently, from effects of severe or sudden lowering changes of temperature and condition ; while the want of these in any degree, or the existence of circumstances of an opposite character, will, according to their degree, by lessening the energy of the vital powers of excitability and resistance, have the effect of ministering

to the dominance of the devitalizing and depressing action of the poison on the temperature and the well-being of the body:—

and again, the climate, the season of the year, the weather, the turns of the daily routine will all have important effects on the modes and the balance of these two contending actions of the carbonic acid on the bodily system and its temperature;—the warmth and brightness of climate,—the return of a season of the year, at which the general warmth and the stimulation of sunshine is great,—warmth, fineness and stillness of weather,—an atmosphere in that condition, not necessarily warm, which is called “close” and which may be due to something in the composition of the air, as I think it frequently is, or to a want of free circulation of air from the confined character of the locality or to a temporary overclouding by heavy thunder-laden clouds suspended on a still and shallow lower air,—the warmer and more comfortable, or oppressive, periods of the day; the period when the sun is highest and most beneficent, or when ordinary daily avocations or pursuits are in active and spirited process, or the period in the night when the body is at perfect rest and has begun, under the protective coverings of bed, to be restored from the fatigues of the day gone by,—all these will tend in their degree to favour the irritative action of the carbonic acid and restore or raise the body-heat;—

but a climate characterized by much moisture, high wind and chilliness,—a season of the year, in which storms prevail and the sun’s power is small,—a cold or wet and windy weather,—the daily periods of evening, night and morning, when the sun gives out less of stimulating warmth and the air becomes more moist and chilly, more particularly if the ordinary artificial means of protection and warmth, such as competent personal covering,

housing, firing, bedding, &c., are in some measure neglected,—will have the opposite effect, will help to subdue, wholly or in part, the tissue irritation and aid the devitalizing action in lowering the temperature of the body;—while it is further true, that, in the midday hours, when the sun shines most warmly and by its heat the air is in some degree of expansion, the carbonic acid contained therein is also in the same degree rarified, but in the evening it becomes more condensed again and may also be associated with a falling dew as a solvent and a vehicle, in the night becomes more intensified in both respects, and in the morning remains dense and prepared to be active until the sun has power again to warm and rarify the air; conditions which must necessarily emphasize the above-mentioned effects on either side at the different periods of the day and night.

From the number, then, of these and such like factors, and from the fact of the occurrence of any of them being generally independent, more or less, of the others, yet frequently coinciding, many or few of them, and of different degrees of intensity, it will be evident that the variety of possible proportional combination formed by them, or by some of them, and the variety of the degree in which they will affect the temperature of the body, will be very great. The temperature in one case may be very high, by reason of the preponderance of the irritative action of the poison being maintained and intensified by the co-existence at the time of most or many of the conditions which favour that action; or in another case it may be very low by reason of the oxidation-preventing and depressing action of the carbonic acid being aided in its subjugation of vital energy and heat by the coincidence of most or many of those lowering circumstances that have been mentioned; or in other cases, by the interaction involved

in the coincidence of some or many of the above conditions of opposing tendencies, the temperature may fail to be markedly affected either in one direction or the other; and by this interaction all degrees of temperature from very high to very low may be determined.

Nor is it only the temperature that will thus variably be governed; other evolutions of organic processes will have a like variability, according to the varying balance, or preponderance of one or the other, of the opposing influences of such factors as have been instanced. Results of altered constitution of tissues from persistent concurrence of the irritative and devitalizing actions of carbonic acid, which have before been referred to, will be variably modified by circumstances; the coincidence of those extraneous conditions that tend to favour the forces of vitality will increase the exaggeration, which the irritative action of the poison produces, of the natural expenditure of tissue; on the other hand the prevalence of those opposite conditions which have a depressing effect on the vital powers will strengthen the devitalizing action in making ineffective the removal of waste material, and even in adding to the extent of tissue rendered effete; so that the degeneration of tissue, which must follow from these two intercurrent actions, will show in varying circumstances a varying balance of result, and yet it will never cease to proceed in some degree; in consequence of which in course of time the several solid tissues of the body will, according to their several natures and positions, become changed to a lower grade of organic constitution, with an increased proportionate bulk and density, and an inferior power of activity of functional life.

Such degeneration may be contemplated as occurring most extensively in that tissue which is most extensively distributed throughout the body—the areolar: as this

tissue and the fat, which rests in the interstices of great part of it, which may however independently of it be in part consumed in the general economy of the system, become wasted and renewable, the interstices will become occupied, gradually more and more, and even the tissue will to some extent become replaced, by a certain, carbonic-acid-laden, antiseptic and therefore very abiding material of but a partially organic constitution; which, by the continuation of the process, will continue to increase, until in the many different situations in the body it reaches limits which the natural relations of each situation imposes on it, as to bulk, density and direction; while the varied circumstances of these situations and the consequent variation in the extent and form of the accumulation of this material will only modify and direct the encroachment which it will necessarily make on the natural accommodation of parts with which it is in relation. Its distribution and consequences may be illustrated in such instances as the following:—

in the superficial areola tissue around the loins and belly, where an appearance of obesity will arise and remain; and in the condensed or fibrous tissue of the lumbar aponeurosis, which it will thicken, tighten and cripple, inducing or preparing the way for the affection which we speak of as lumbago;—

in the areolar tissue that is in relation with important viscera in the pelvis and abdomen, whose accommodation and well-being will be affected by its changes of density or bulk;—

in the areolar tissue of the walls of the intestinal canal, where it will impair the flexibility of the canal and impede the freedom of its muscular activities, thus bearing a part in establishing that passive constipation which has been before spoken of;—

in the areolar tissue, condensed or otherwise, that is found constituting the coverings, divisions, or part of the substance, of organs of importance in the abdomen, as liver, spleen, kidneys, &c., in which it will, by its increased bulk and inelasticity, and perhaps by further influence from the carbonic acid with which it is sodden, render the organ unfit to execute effectually its function, vitiate secretion, derange variously the circulation within the organ, and induce a condition, depraved or actively diseased according to the direction given by other coincident causes, and in either case tending to grave consequences of both local and general importance ; —

in the areolar tissue of the substance of the lungs, where the increased density and deadened elasticity, which it will cause there, will hamper and compress the air-cells and capillaries, passively but powerfully resisting expansion, imposing a further measure of hindrance to the oxygenation of the blood both by a solid mechanical resistance to full inspiration and by means of the presence in it of a saturation of carbonic acid, and will proportionately to the duration and potency of its invasion impair the mobility, capacity and efficacy of the whole function and apparatus of respiration ; —

in the areolar tissue of the thyroid gland, in which the same increase of substance will occur, but will be, in virtue of the easy slackness of its relations, an increase of bulk much more than of density ; while from the large vascular endowment of the gland it may readily be apprehended that, the convection thereto of the carbonic acid received from inhalation being the more voluminous and direct, so this increase will be the more developed and pronounced ; and, again, this increase of substance may irregularly, by pressure or obstruction, cause mechanical involvements of the blood-distribution, from which would

arise further untoward conditions; remarks which I think may be equally predicated of both spleen and thyroid;— in the areolar tissue that fills up certain spare places and preserves continuity in the relations of other structures, where the increase of bulk will have varying discommodating effects on these other structures according to the direction of the control exerted on it by the varying firmness of its boundaries, resisted by the firmer of these, but encroaching upon or even displacing those of a more lax or movable character; as, for instance, in the orbit the increase of bulk in the cellular tissue occupying much of its posterior extent, resisted generally by its boundaries of bone except in the direct front, will push forward the softer structures in front and cause the eye-ball to protrude with unnatural prominence, giving a remarkable, unpleasing appearance to the countenance, which yet will be but a local sign of a process that has been taking place in all the body;—

and in all the superficial areolar tissue, in and under the texture of the skin, the same increase of bulk will gradually be established, with loss of elasticity and comparative lessening of vascularity; in some places, as in the hands, the thickened integument will become stiff, blanched, and moulded by the habits and uses of the part; and, more generally, the surface will present, with a pale appearance, a condition of passive receptivity and temporary retentiveness, like dough, of impressions of hard or resisting objects against which it has been pressed.

The muscular tissue also, in the same manner as the areolar and continuously with it, will be subject to the same actions of the carbonic acid, wasting and devitalizing fibre after fibre, accumulating interstitially an encroaching and impeding, half antiseptic material, and therewith establishing the same degeneration; which will everywhere

have the necessary consequence of diminishing available muscular power; the voluntary muscles will gradually lose capacity of stimulation by the nerves and ability of either effort or endurance;—and the involuntary muscular systems will suffer similar loss;

in the circulatory system, the action of the heart depending on its power as a muscular organ will become permanently weaker, this tending along with concomitant conditions in the lungs to enfeeble respiration as well as circulation, and, the same condition involving the arteries, will probably betray itself in the character of the pulse;

in the digestive tract, the muscular movements of the walls of the stomach upon its contents in digestion will become lessened in energy and in freedom, and the process of digestion retarded; while the muscular power of the intestines which exerts itself to carry forward their contents being similarly impaired will tend, along with other conditions already noticed, to allow a permanent habit of passive constipation to become established;

in the bladder, the muscular power which enables it to retain the urine, and also that which effects its discharge, being both similarly impaired will give rise to consequences easily traceable and more or less distressing; although these may at times variably be masked or modified by the variableness with which varying circumstances may or may not encourage the direct irritative force of the acid;—

and in all parts where muscular fibre, striped or unstriped, has a place, a loss of some degree of power will occur by reason of this degeneration.

And in the nervous tissue, from the same actions of the carbonic acid, the same processes, having analogous degenerative consequences, will occur;—

in the cerebro-spinal mass, the material of degeneration

will gradually be formed in the same way as has been described in regard to other tissues, interstitially invading the nervous substance, and, in the long continuance of the process, more or less replacing it; by which, some of the brain functions perhaps will be more interfered with than others, but the edge of all in general will be dulled, whether they are associated specially with the activities of the body or of the mind;

in the nerves distributed throughout the system, their substance partaking of the same degeneration, their faculty of carrying sensational or executive communications to and fro will be notably injured;

and the advanced consequences may be expected to be—a general loss of power of every kind; a weak and tremulous unsteadiness of the whole frame, though mostly of the head and limbs, showing itself during both stillness and action; a growing incapacity of co-ordination of movement; a diminished capability of continuous connected thinking; and an increasing disability to give to thought its due expression in action;—all these consequences, even to their extremest degree, it may be noted here, being among the characteristics of “cretins,” whose miserable condition has been, by common and long-standing consent, attributed to, and named from, the fact that the drinking water of these poor creatures is vitiated by a large amount of chalk, abundantly held in solution by a still larger amount of carbonic acid,—of these two the carbonic acid being a far more potent agent on animal nature than the chalk or lime.

Besides these three widely ranging and influential tissues,—the areolar, muscular and nervous,—in other tissues also, in all the tissues and constituents of the body, will this same process of degeneration take place; only varying, both as to speed and extent of change, according

to local conditions,—the facilities of introduction of carbonate acid, the interferences with the elimination of it and of other matters, and the vital energy belonging to the tissue and situation.

Thus, cartilage will become less and less truly organic, less fit for its purpose, liable to be worn down or altered in shape by pressure, &c., instead of adequately producing repair of its own true substance; will be liable to be the seat of enduring, if not violent, pain caused by the saturation of the irritant acid poison and other incidental circumstances; will, in short, induce a train of conditions and symptoms such as display themselves in chronic rheumatoid arthritis,—say, for instance, of the carpus; and even bone will suffer in the same way,—losing by degrees its vitality as an organic tissue, becoming weaker and more friable under the application of any violence, less capable of any effective organic repair, though not less solid perhaps; and will, by the continual accretion of degenerate substance on the one hand, and the wearing away of substance by the pressure of some structure or function in its immediate relations on the other hand, take on in course of time some changes of shape and adaptation,—as, for instance, when the aged lower jaw bone has its angle and alveolar process worn away or, by a solid accretion of degenerate tissue in the alveoli, the teeth are more or less extruded, or when a bone, say the neck of the femur, is broken and found incapable of reunion because there is not sufficient organic constitution left in it to accomplish repair, or when cancellous bone becomes, in the progress of age, more solid and has its cancellous character lessened or obliterated.

Such are the pathological conditions which would be produced slowly and gradually in the course of a very long continuance of endurance of the presence of an excess,

not very remarkable in degree, of carbonic acid; they may never have manifested any acute stage at all; never have shown that disturbance of nervous influence from the acidity of the poison, which results in an elevation of bodily temperature capable of being measured by the thermometer and discriminated as fever; never, in short, in all their course have reached to any degree of obtrusive ill-health, which could be instanced as a disease.

But if we suppose a quicker and more aggravated course of these conditions, from the carbonic acid being present in greater volume in the air and more intense and powerful in its invasion on health, it may naturally be conceived that such degrees of derangement of the well-being and processes of life will be reached, as will amply claim to be looked upon, and treated as, disease. To such a severer range of cases it is now proposed to turn attention and, with the aid of past conclusions, to explore what might be probable trains of symptoms, which should characterize such disease.

Let me suppose the case of a man, brought to live in an atmosphere, which contains perhaps three or four times the proportion of carbonic acid, which is stated to be ordinary or normal. Here the consequences, which have been indicated chiefly in a chronic form in the preceding pages, will be expected to show themselves in a much more acute form, and the unwholesome processes that take place will make themselves evident, not so much by presently discoverable results in tissue, as by their disturbance of the natural conditions of the body and the impairment of the present exercise of organic functions.

But to contemplate these in the detail proposed here, account must be taken of other circumstances, as the various idiosyncrasies of human constitution; in which, and consequently in the observable phenomena in them

resulting from the actions of the poison, there is, and must be expected, a great diversity. The range of diversity, however, of human constitutions is so wide, that it would be impossible here to consider more than a representative instance or two, such as may indicate with sufficient clearness the common characters and the nature of the differences, which should be expected in the cases of carbonic acid poisoning, which I propose now to consider. I will refer, therefore, to two leading diverse instances of common physiques, presenting, as I apprehend, cases which are extreme on either hand in regard to our enquiry; in a series between which will be a large number of cases, gradating from one extreme to the other, partaking of the characters of both, but leaning more to one than the other extreme, and offering a wide field for diversity of description of the apparent disease. I will take, then,—first, the case of a young man, florid, vigorous and active,—and second, that of a subject who is no longer in the freshness of youth, perhaps naturally of a sallow complexion or languid frame, and of a more subdued nervous disposition;—in either case a total absence of any recognized condition of ill health.

When the subject has commenced residence in a place over-laden with an extraordinary proportion of carbonic acid in the atmosphere, he may begin to suffer noticeably from it very soon, in not many days even; or the stability of his health may be so firm and equable, that months may elapse first; and the rapidity or delay will be governed, not altogether by his own equipment of health, but also, and perhaps in greater measure, by the changes that may occur in atmospherical conditions during the period, and by his manner of life, including his occupations, housing, clothing, &c. and personal habits. But the manner of his being affected, the character of the symptoms which he

will display, will be in a preponderating degree determined by the natural balance of forces in his constitution peculiar to himself, by conditions within himself.

I have already with some insistence dwelt on the two contrary and opposing effects of carbonic acid on a living organism, the irritation caused by the acidity of its nature, and the quelling of vital activity caused by its property of preventing oxidation; these, *cæteris paribus*, would naturally eventuate in a sort of alternation of the prevalence of each, consequent on the rhythmical character, the alternation of effort and subsidence, which is observable in all the energies that reside in animal physics. In all such prolonged organic struggle, these alternations of energy and subsidence will be determined, as to their force and duration and recurrence, by the amount of physical force belonging to the organism, with perhaps the encouragement of some coincident extraneous circumstances belonging to the environment of a nature to promote organic vigour, on the one hand; and by the power of exhausting or overcoming it, assisted by whatever surrounding circumstances of a depressing nature there may be, ranged against the organism on the other. So in the case under consideration, in the struggle between the organism and the invading poison there will be a rhythmic alternation of prevalence between the power of the organic forces and the power of the poison; and the period of each prevalence will be determined not only by the proper forces of the two opposing powers, but also by the circumstances of the environment which tell in favour of the one or the other; the more the organic forces are endowed with sensitiveness of nervous power and excitability of resistance, the more violent will be the combat on their part, and the more they are possessed of resources of staying power in the natural vigour of the

constitution, the longer may the struggle be expected to last; and the fever may rise to such a degree and be maintained for so long a duration, as to endanger life; but, the organism being at best an exhaustible quantity, the power of the poison on the other hand not being subject to exhaustion, the end for the time will probably be the cessation of the struggle on the part of the organism until some stimulating or recuperating assistance arouse it anew; and at each successive renewal of the fight it will be found that strength, some more strength, has been sapped from its organic resources. And, considering that, in the struggle between an animal body, which is subject to conditions that pass away and recur and vary at different periods of the twenty-four hours of the day and night, and an inorganic pervading and surrounding power, which is only subject to the one variation, that its intensity may be a little less at some easily determined periods than at others, it must rest with the weaker combatant, the animal constitution, to renew or lay down on each successive occasion the combat, it should not be difficult, in the light of conditions already treated of, to lay down the probable daily scheme of these recurrences.

Thus, in the early part of the day,—when the body has had a night's recovery in bed from the fatigues of the day before, when the organic powers have received some resuscitation also from food and are not yet affected by the labours of the day now begun, when yet the call to these labours are bracing up the vital energies to resumed effort, especially when the growing warmth of the day is making itself more or less felt and is imparting some degree of reviving stimulation to the organism,—it will be found that the force, and in like manner the feverishness, of the conflict waged by the constitution against the hostile invasion of the carbonic acid will be promoted, and, accord-

ing to the measure of its sharpness, will be recognized as "an attack of fever;" which may be sufficient to incapacitate the sufferer from continuing to discharge the present duties of the hour, or even may be so severe as to strike down entirely his effective strength and lay him low on a bed of sickness. This feverish condition will last as long and in the same degree, as the conditions of vigorous effort which promoted it will last; but these conditions themselves are all more or less fleeting and exhaustible,—the recuperation of the preceding night will soon have yielded to fresh exhaustion, the restoration of the morning's food will have passed away and probably some degree of sensible weakness and derangement affecting the organs of nutrition will hinder a due and sufficient amount of fresh nourishment being taken, the morning's animation of resumed duties will have yielded more speedily than in health to the fatigue of these, and the sum total of strength and stimulation belonging to the organism will be expended.

With this gradual, and not slow, expenditure from the sources of physical energy, there would also arrive general conditions, which would be all on the side of the prevalence of the overwhelming power of the poison; the temperature of the external world would cool as the day waned; and, the heat of the atmosphere belonging to the warmer hours of the day being reduced by the chilling approach of night, there would come, by subsidence, a still more oppressive intensity of carbonic acid in the lower air. Then the feverish activity, representing the struggle of the organism, will fail and be subdued; and the interstitial irritation of the acidity of the poison will be evidenced by a different, in some points almost a contrary, series of phenomena;—there will be experienced an abiding malaise in the whole frame and an active aching in the

principal fibrous structures, with sensible loss of vigour, and at the same time inability to receive the recuperation of rest; excited tremors of muscular elements, from the action of the irritant poison on the nerves which govern them, will prevail and produce spasmodic shakings of the whole system; and a sensation, more or less acute, of coldness and chill will permeate the body by reason of the suppression of oxygenation and metabolic activity in the tissues by the carbonic acid and this being made sensible by the irritable sensitiveness which it creates on the nerves; while the clinical thermometer will probably give evidence of an actual diminution of the heat of the body,—a diminution which may be notable only from contrast with the temperature observed during the fever in the daytime, or may decline to a point even surprisingly lower than the normal degree.

It has already been observed, that one very extensive means, by which the body seeks to cast out the offending presence of an excess of retained carbonic acid, is the action of the skin, which extrudes the poison in a quantity of fluid; it is therefore probable that in the cases now under consideration this process will early be set in action, even before the invasion of carbonic acid has proceeded to the degree of rousing any severe febrile action. The activity of the function of the skin is of very various degree in various individuals; and the consequent uncertainty of its efficiency will add to the uncertainty of forecast; but this may be said, that, while it is hardly possible that in any individuals this function should be altogether in abeyance, in those in whom its efficiency is small the onus of the poison will be the more thrown upon the other powers and there will be the greater likelihood of severe fever; and in those in whom it is naturally of very active efficiency the fever may never become very

high or may even escape marked attention; while in ordinary constitutions the elimination of the poison in fluid from the skin in some measure will precede and co-exist with the fever and continue after the febrile excitement has become exhausted or subdued. In the conditions therefore to which reference has been made, when lowered temperature and aching and restlessness have succeeded the feverish struggle of the day, when after weary endurance some rest is procured by persistent recumbence and determined quiet and a certain small amount of recuperation of the exhausted forces of the system is thus obtained, the skin will afford a facile means by which, almost passively, the system will seek to cast out its enemy, and the surface of the body will become bathed, more or less profusely, in perspiration, until some equation of tolerance of the still remaining amount of carbonic acid is attained, that is, until sufficient of the acid is got rid of to admit again of some evenness of physical function and the way is thus prepared, probably at some period about the middle of the night, for taking advantage in some degree of the restoring influences of further rest, &c. Unusual and apparently unprovoked transudation from the skin, then, must be looked for as an essential element in this disease, for disease it certainly may be termed, and it will probably occur before any fever has been remarked; will in ordinary cases even co-exist in some degree with the fever; and will more profusely exhibit itself in, or after, the subsidence and after the body, having been worn out by its struggle, is placed in circumstances of rest, even growing a little in profuseness for some while coincidently with the progress of liberation of the powers from the poison. It is also to be supposed, that gradually, as the perspiration extrudes more and more of the poison, the aching, the

restlessness and the quivering tremors of the muscles will disappear, the body thus becoming more capable of taking benefit by rest; and probably by the morning a comparative renewal of comfort and welfare and even of strength may be sensible to the feelings of the subject.

And now the subject will commence a new day; in which, with also somewhat less power of resistance in his natural forces, he will have to undergo a similar procedure of contention with the invasion of carbonic acid that poisons his environment, a similar course of diurnal phenomena, accentuation of nerves, fever, subsidence, perspiration, and partial recovery; to be repeated again and again in the days following, unless medical treatment succeed in allaying and improving his condition or he escape from the poisoned environment.

But besides this peculiar succession of conditions characterizing each day's experience it is natural that other conditions of a less periodical description, such as have in foregoing pages been attributed to the action of carbonic acid gradually invading the physical constitution, will have their place. Among the first of these to supervene, perhaps long antecedent to any appreciable actual fever, will probably be headache, not perhaps very acute, but displaying a character involving in some measure the peculiarities of the head symptoms described by Taylor among the early symptoms of carbonic acid poisoning.

Following very closely, or even accompanying, this symptom, there will be, both from the influence of the poison in restricting the required oxygenation of the tissues and also the nerve-exhausting effect of its acid irritation, a general, apparently unaccountable, sense of languor and muscular weakness and susceptibility of fatigue.

Then, by reason of the manner, already set forth and explained, in which the carbonic acid acting on the mucous

membrane causes its secretion to become viscid and difficult, the mouth and fauces will labour under a sensation, which will be easily mistaken by the distressed subject for a feeling of thirst, continual and unappeasable; the most essential centres of digestion will be impeded and the appetite disordered; and the intestines will be hindered, both by the viscidly of their surface secretion and by the loss of muscular energy, from passing their contents along duly as they should, becoming persistently and troublesomely costive.

Sensations also of changes of external temperature will be rendered keener; heat will be less readily borne, being aggravated by the internal interstitial heat generated by the irritation of the acid, which external heat will tend to foment; and cold will in like manner be intensified by the chill of the deadening power of the acid retained in the organism, which again external cold will tend to increase.

It has already been observed that an unusual facility and profuseness of perspiration will be a characteristic, which will be displayed most intensely when the exhaustion and distress of the evening in a feverish case are beginning to be assuaged by a little return of restoration in rest, but will also have existed in some degree from a much earlier stage, from the first period when the poison had acquired an extensive or general hold of the system, and it will continue ever after unless, or until, in happier surrounding circumstances and by treatment the system is freed from the dominance of its presence.

These may be regarded as the probable leading phenomena of such a disease in general; but, as has been already pointed out, in any individual case the balance of these, the preponderance of one more than another, involving perhaps considerable difference in the aspect of

the case from that of others under the same observation, will be largely determined by the peculiar balance of the physical forces belonging to the natural constitution in that case. Therefore, taking the two extreme instances, which I have before indicated,—a young, florid and vigorous subject on the one hand, and a less sanguine, perhaps weaker, or more spent subject on the other, it may be considered in what manner and how far the personal physical endowment may probably affect the character and tenor of the disease in either of these instances and, easily following from them, in the large range of cases that must naturally lie between them.

The warmer vitality of the first instance will occasion a more vivid excitability under the irritation of the poison and, especially if he be young, the staying power will be the more immature; the expenditure therefore of the organic vigour will be more rapid, while the reserve of strength will be less. In consequence of this the excitement of the irritation of the poison will be from the beginning more disturbing, will sooner mount up to distinctly declared fever, and may increase to a degree which may involve danger to life. In the earlier stages, when fever has not yet been reached, the sufferings from headache, facility of fatigue, &c., will either be more severe, or seem so to the personal appreciation, from the intolerance natural to the temperament and from contrast with previous habitual briskness of energy; and in the after stages, from the more rapid expenditure of energy, the decedence from the state of fever to that of exhaustion and chill will be greater and more calamitous, and in the process of the disease the loss and depreciation of general health and strength more rapid and complete. Subjects of this class will probably have more acute suffering in all the symptoms,—more excessive transudation from the skin, an

acuter restlessness, a sharper aching in the fibrous structures, more intense fever, severer tremors of the muscular elements, greater proportional collapse in the stage of chill, but on the whole a more manageable constipation, which will sometimes be interrupted by an irregular irritation of the bowels or even some scybalous diarrhoea. If the subject survives the period in which his organism can still carry the battle to fever height, his organic vigour, more than in other instances, will have been exhausted in the fierceness of its previous struggle, and he will the sooner come to live that life of weighted and reduced energy and value, which the persistent deadening presence of a retained oppressive amount of the poison must necessarily bring about.

On the other hand, in the second instance, the naturally more attempered and moderate array of organic forces, even if often associated with an acute nerve sensibility, will enable the constitution to bear with less serious disturbance the resistless invasion of the carbonic acid, yielding less to the excitement of its irritation, and undergoing more of its deadening and chilling influence. There will be consequently, from first to last, less of that tingling irritability in the tissues which is so exasperating in the warmer natures, though perhaps a great deal of suffering from that weary unappeasable aching of fibrous structures, as in the loins and limbs. There will also be less elevation of the temperature of the body above the normal standard; but, succumbing most to that main character of the poison, which restricts oxygenation and limits vital activity, the organism will have a lowered temperature and be restrained from much, if not from all, display of recognizable fever. The skin will doubtless act excessively in these cases, as well as in the others, for the elimination of the carbonic acid; but the transudation will pro-

bably be more continuous in character and less hotly liable to occasional accesses of profuseness, except on bodily exertion or imported stimulation, on either of which a more than proportionate increase of perspiration will be evoked. The progress also of apparent interference with the condition of the digestive mucous membranes will be gentler, though not less extensive and persistent; thirst will be less dry; appetite will show a less marked depreciation from its previous capacity; constipation of the bowels will grow from an early period and will display less irregularity of continuance. And the effective strength of the frame, both in effort and in endurance, will be found to decline persistently.

The differences between any one human constitution and another, in the long series that intervenes between the two extremes cited in regard to the present subject, are so many and so complex, that they cannot be contemplated as differences only in degree, but in kind also; yet, with respect to the consideration of the effects of carbonic acid thereon, the cases will approach more or less distinctly, and manifest more or less preponderatingly the characteristics of, one or the other of these extreme types and so form a series occupying the range between them.

The course which the depraved health will follow, after the gradual subsidence of the acuter manifestations, after the daily cycles and alternations have ceased to be very marked or to display any very exalted excitement, and which will result from the diminution of vital vigour combined with continued effect of imbibed carbonic acid, necessarily augmented continually, in whatever small degree, by continued imbibition, will be of essentially the same nature in all cases; though the physical exhaustion, in which this chronic stage will commence, may possibly be greater in the warmer-blooded natures, than in those

of less excitable vigour, in consequence of the previous greater violence of their struggle. This depraved health will chiefly consist in the obvious development of some of those conditions, which, in previous portions of this essay, have been traced and described, as necessarily or probably following the presence of an excess of free carbonic acid, imported into or remaining in the tissues of the body, and exerting in them its essential and characteristic properties. But these conditions will be sooner and more prominently observable and will attain a greater prevalence over the system, than as previously contemplated and described, inasmuch as the cases now under consideration are supposed to have been, and still to remain in some degree, under the action of a more overwhelming quantity of the poison in the atmosphere; while the particular disturbances, which they must occasion in the various economies of the system, will be variously either of a general character or of a more marked direction in one way or another, according to the natural personal bodily habit or idiosyncrasy in each individual case. The following, then, will probably be among the noticeable features of these cases;—

all the tissues becoming loaded, as has been previously dwelt on, with a slowly increasing, semi-organic, carbonic-acid-laden padding of unremoved produce of tissue-waste;—

the skin, and the immediately underlying cellular tissue, will become thicker, denser, more opaque and colourless, and inelastic, impassively susceptible of receiving and retaining for an appreciable time recognizable impressions of external resisting substances, against which it has been pressed;—

and the function of perspiration will become permanently, almost passively, more facile and abundant;—

the mucous membranes being affected in like manner, the

secretions of the pharynx will be habitually more or less viscid and troublesome ;—

the appetite and function of digestion will be impaired ;— and, especially, the activity of the bowels will be impeded and constipation become habitual ;—

the substance of the liver becoming interstitially hampered, and its size or density increased, perhaps irregularly, its functions will be disordered or precariously executed ; and, in the event of any accidental local congestion, acute and serious results may follow ;—

in the kidneys the same process of alteration of tissue may bring about a condition resembling, if not identical with, Bright's disease ;—

the spleen, under the same process of alteration of tissue and consequent alteration in the relation and adaptation of its structure to the vascular arrangement lodged therein, will become variously and precariously enlarged and deranged, so as perhaps to produce considerable suffering and, possibly, a dangerous liability to serious, or even fatal, injury on the application of violence ;—

the thyroid, chiefly in the female for more reasons than one, and the prostate in the male, will also in the same way acquire increase of size and density, which in either case may be the cause of much inconvenience and distress ;—

the lungs, suffering the same process, will progressively, if slowly, fill up from the terminal lobes and become sodden, like an ill-kept sponge, with moist unremovable waste matter saturated with carbonic acid ; and their capacity and elasticity both impaired ;—

the heart, besides being, in some less degree, subject to a degeneration of tissue of like nature, will be much affected in its function by the condition of the lungs ; its action becoming weak and often irregular ;—

the nervous system will also show signs referable to a possible similar degeneration of its substance; the powers of the brain will be duller, weaker, and less capable of continuity of effort; while the disposition will be more irritable; and the nerves will have less steady power of command over the parts which they supply;—

the thermometer will be almost sure to reveal, as the case goes on, evidence of diagnostic value; the temperature of the body will become permanently lower, never in any occasional feverish illness rising so high as it would formerly have done, and in other circumstances always showing a lower reading than normal;—

and the general condition would be marked by an inertness and subdual of all the powers, resembling a premature old age.

I have, then, now offered some amount of detail, both of the symptoms and course of what may be called the primary or acute disease which would result on the introduction of a person into an atmosphere containing a large excess of carbonic acid, and also of the consequent or chronic results which would succeed these and grow under a continued, though perhaps unequal, maintenance of exposure to the poison. Yet it is not necessary to suppose that all, or even most, of these results would be likely to appear in all cases; for there are determining factors peculiar to each individual constitution upon which it is impossible to generalize.

But, again, the diffusibility of carbonic acid through the system, when once imbibed or retained there, has been shown to be so rapid and general; and its degree of noxious excess in the atmosphere may be so moderate; that it is conceivable that the processes of its action on the organic tissues might take place very slowly and equally in all parts of the system simultaneously; and, in

such a case, if this general process were to go on at a sufficiently slow and steady rate, it might be that the vital forces of the patient, even while gradually and surely declining together, would yet continue a fair and mutually proportionate appearance of working order without any startling breakdown or irregularity, and that he would still be unobservant of his really too rapidly failing vitality.

Still further, it may come to pass that the one quality of carbonic acid, which seems to be capable of assisting favourably the conditions of health,—its antiseptic quality,—will here prove valuable. The acid, continuing its inevitable but slowly advancing hostile action on the organic tissues, will at the same time probably be as hostile and even more effective in its destructive action on the disease germs, which are the essential factors of some common serious diseases. It would, therefore, according to the degree in which it is present in appropriate strength, prevent or quell the onset or activity of such diseases and save the patient *pro tanto* from them. And thus he, undergoing only a slow, though sure, process of gradual extinction by the somewhat moderate excess of carbonic acid around, and in, him, would by it be kept in a condition of continued protection from these common serious diseases and might have his life prolonged, though feebly, to a very extended span of years.

SECTION IV.—I think I have now indicated sufficiently comprehensively and distinctly both the general principles and the prominent particulars of the action of carbonic acid on the physical constitution and of the disturbance and injury to health and life,—in other words, of disease,—which such action may be expected to induce. It now, therefore, falls that I should revert to the question, which led to this enquiry into the nature and processes of the

action of this poison,—how far there exists a similarity or identity between the consequences of carbonic acid, speculatively and reasonably forecast, and the consequences of exposure to, what has been recognized by its effects as, “malaria,” known to observers. And I think that it must be conceded, by those who have been good enough to follow closely my reasoning and are at the same time well acquainted experimentally, in their own persons and in their professional practice, with the manifestations and developments of malarial disease,—that there does exist a marvellous coincidence, both of procedure and consequences, between the two;—that, in fact, they are so alike, that there is little or no ground left for disputing their identity.

It is true that I have not traced the consequences to health of some sulphuretted products which are shed into the air over some marsh lands; but these exist in such small quantities, even where they are to be found, and are not to be found at all in so many places in which malaria is recognized by its effects to exist, that they do not seem to afford justification for spending time or reasoning on their further investigation. And it is left to me to hold that carbonic acid may well be taken to represent nearly, if not quite, the entire power of malaria in whatever localities the manifestations of “malarial disease” display themselves.

It will have been observed, that, in regarding the morbid consequences of a carbonic acid invasion of the system, I have assigned a much larger space to the depressed and chilled conditions, than to those which may be termed feverish; and this is in fact the relation that is borne between them in cases of malarial disease. I have described periods of exalted bodily temperature occurring when certain circumstances are present, which tend to favour the

powers of the constitution in their struggle to rid themselves of the invading "poison"; I have thus placed these periods in the light of wholesome efforts in the cause of health, which have their source and strength from the springs of life and have regarded the alternate stages of depression and chill as the potent and unmitigated manifestations of the disease. It is in the same way that I look upon the alternations of fever and ague in malarial disease, the latter being the true characteristic representation of the disease, the former the wholesome effort under favouring circumstances of the forces of nature. It is my view that the ague is the disease and the fever the intermission, and that primary or acute malarial disease, instead of being called "intermittent fever," would be much more properly called "intermittent ague"; the ague or depressed stage being the intermitting achievement of a subjugation, that is destined to become in time more equable and abiding and to decline into a permanent depression of vitality, which may be demonstrable only by the thermometer or may be fraught with lasting serious disparagement of health.

What I, then, think to have been a misapprehension of the true circumstances of the case has led further to this more equable and abiding subjugation being viewed as an "acclimatization" of the constitution to a malarial atmosphere; it has been held, because the recurring febrile disturbances seemed to grow less and disappear after some prolonged series of alternations of the "intermittent fever," that the constitution has been "acclimatized" and rendered more safe, it not being remarked that the constitution, now free from fever, no more remains in, or ever returns to, its original vigour; its freedom from fever being, indeed, the sign and, in the earlier stages of decadence, almost the measure of the loss of vital energy.

It is in accordance with my view, of the identity of 'carbonic acid' with the matrics obscurely referred to as 'malaria,' to hold, as indeed I do, that there is no true "acclimatization" of the human constitution to a malarious region possible or conceivable.

I do not purpose now to introduce any description of malarial disease from the standpoint of an observer of cases recognized as such, for it has so often been treated of, by textbook writers and others, that it does not seem necessary for me to do so. Yet perhaps I may be permitted to say, that the descriptions of it which have appeared in various works of great learning, true descriptions as far as they go, are in my opinion very incomplete;—partly because the clinical thermometer had not been sufficiently constantly employed or its application extended to every stage of the disease, including the after stages of permanently deteriorated health which succeed to the early, more acute and easily observed phenomena;—and partly because our most voluminous writers have not been those, who have had most practical opportunity to devote their observation and their professional skill to the consideration of the circumstances attending or characterizing its course, or to the free elaboration of a reasonable system of treatment, but rather who seem to have easily allowed themselves to adopt and descant on the limited views of others, their predecessors, dating from the first publication of the discovery of the beneficent controlling power, which the then-called Peruvian Bark and its derivative Quinine possessed over the intermittent fever, to which alone almost they confined their conceptions of the disease. It has however been so far distinctly and illustratively described, that it is generally recognized without much uncertainty: and it has been stated also above, that its varied phenomena and eventua-

tions are exactly those, which I have constructively elaborated from a careful consideration of the effects and modes of operation, recorded and deduced, of carbonic acid poisoning; so that now there is no more left for me in this direction, than to present a few illustrative cases, drawn from actual records in my possession, which will, I venture to think, emphatically help to establish the views which I have endeavoured to set forth.

1. The first case which I select is that of a woman, of about sixty years of age, looking older, spare, fragile, and nervous in demeanour; with a long history, still continuing, of dyspepsia; nervous weakness; weak and excitable heart; pain and sense of weight at spleen, which was enlarged; a constant liability to "cold chills" and "hot flushes"; and habitual constipation;

living in the bottom of a long, low, wet, very often foggy, alluvial valley; beyond the farther end of which rose a lofty range, lying in a direction transverse to that of the valley, of chalk downs.

During the time in which, almost continuously, she was under my observation and care, which was for about eight months before her death,—a period too long for me to attempt to describe in daily clinical detail,—the following were the leading symptoms of her case:—

very little remaining muscular, or any other, strength; apparent decadence of organic power in all directions; intense and seldom relieved nervous weakness and excitability; twitchings frequently in limbs; headache; giddiness and "swimming" and "noises" in the head; excited cerebration in feverish passages; gentle delirium; stomach very weak and disordered; appetite always at zero, notwithstanding gnawing and painful sensations of emptiness and sinking; sometimes quite unable to take

any food or even to tolerate its approach; frequent vain retchings from empty stomach, sometimes excited by windy spasms, sometimes by the mere presentation of food; occasional vomiting of foul brownish mucus, very tenacious, now and then a little streaked with blood; much eructation of wind; frequent severe suffering at sternum, in epigastrium, over the site of the gall-bladder, and in spleen;

liver and spleen both enlarged, and the spleen specially tender at times to pressure;

distressing abundance of secretion of a thick and very adhesive mucus in the fauces, sometimes causing much difficulty in the act of swallowing, sometimes even baulking the endeavour to swallow altogether; this condition evidently extending down the whole length of the gullet and causing endless distresses;

very grave and permanent constipation of bowels, of a somewhat special character,—this character being fully revealed only by repeated enemata, which, when success was reached, brought away large collections of small, well-defined and separated scybalæ, appropriately described by one of her attendants as “just like horse beans”; which seemed to have been first formed separately and then compressed together into a composite mass,—as if the cohesiveness of their material had been increased by the viscidty of the mucous secretion in the bowel, probably in the ileum chiefly, then rolled into separate portions in the convolutions of the intestine (it must be kept in mind that she was a very small feeder), each portion coated over with a distinct covering of very adhering mucus, and more firmly shaped in the sacculations of the cæcum and colon, then massed together by a general covering layer of this thickened secretion and formed into a compact bulk, semi-adherent to the mucous

membrane and immoveable—incapable of being propelled in its natural course and voided— by the diminished power of the gut; the enema, when once or twice repeated, seeming to dissolve in some measure the binding secretion, setting the scybalæ free and causing them to be voided in the volume of the fluid;—this condition of the secretion of the mucous membrane in the lower alimentary canal, so similar to that obtaining coincidently in the throat and gullet, and producing obstruction so similar in its character, inevitably appeared to be similar also in its causation;

gradually increasing restriction of the freedom of breathing; more severe at some times than at others, and latterly almost persistent as well as severe; sometimes probably connected with the weakness and irritability of the action of the heart, enhanced by dyspepsia and flatulence; but for the most part—and consciously so—due to a growing limitation, a shallowness and difficulty, of the capacity and expansibility of the lungs;—she herself expressed it, that her “breath seems bound;” sometimes slight mucous râles could be heard; sometimes a little cough with some expectoration occasionally tinged with blood;

distressing deprivation of the faculty of sleeping; wakeful, restless, agitated; sometimes in much suffering, with a universal aching through body and limbs, or with pain more localized, as in the epigastrium or belly; sleep sometimes entirely prevented by the distressing want of power to breathe freely and a consequent excited nervous apprehension; sometimes, however,—in the earlier part of my attendance,—only a simple, passive, incapability of subsiding into sleep;

action of heart always weak; irritable; often exciting distress and apprehension; no bruit recorded; pulse very

weak, small, of variable but always high rapidity,—from 90 to 120 beats a minute ;

alternations, successive oscillations between two very different extremes, of bodily condition,—depression and then effervescence of functional energy ;—such as commonly characterise malarial cases and are referred to, in their pronounced form, as ague and fever ; acutely estimable by the distressful sensations of the patient herself, recognizable with the clinical thermometer and by general signs open to the observation of those beside her ; very frequent in their occurrence, sometimes more than once in the same day, happening at any time, in the minor degree of intensity that found adequate expression in the terms “cold chills” and “hot flushes” or “hot blooms,” in which I was first told of them ; less frequently in the severer degrees which were only fitly described as “ague” and “fever,” until the course of the case in my hands was about half over ; in the foggy season in which autumn ended and winter began, while the lighter alternations were very frequent, the more severe attacks became more frequent than before and occurred with marked regularity and violence in the early part of each week ; but they soon increased in frequency until, in the latest months, when it is recorded that dense fogs enveloped the whole country, the whole train of phenomena, from the coming on of ague to the close of the fever, occurred twice daily ; it was observed at the time, that these alternating conditions seemed to be determined as to the times of their recurrence by the occurrence of some circumstances, not clearly belonging to the direct activity of the malaria, but concomitant therewith ; as—taking in instance the very frequent oscillations of the latest months,—the morning ague seemed consequent on the natural universal coldness of the early hours, the opening of the house, the probable

first carelessness in disturbing or throwing off some portion of the personal covering at the coming in of a new day, the depression of inanition, the exhaustion from the fever of the night, the dampness and thence the greater susceptibility to chill of the surface of the body after the resolution of the night's fever in perspiration,—the mid-day fever seemed to follow the increasing general warmth of the day, the renewed and established warmth of the house, the recuperation of food albeit the quantity she was able to take was small, and the excitement of the movements of daily life around her,—the evening ague followed the exhausted condition left by the midday fever, the chill of a body bathed in the moisture of a perspiration only recently profuse, the general falling temperature of descending night, and the fatigue to a weakened organism of having passed through the ordeal of another day's distress,—the midnight fever appeared to be re-lit by the assiduities of preparation for the night, the effort and stimulus of the final partaking of nourishment, the getting and settling into the timeous refuge from external chill below the bed-clothes, the sentiment of comfort in rest that bed suggests, with also some excitement of apprehension of what further malaise the night might bring;—and at any time, in an hour of comparative well-being, some irregular incident, such as the coming on of a squall, or a thunder-shower, or the fire going out, would have effect on her and bring on a "cold chill," more or less severe; while some event of an opposite, a warming or exciting, character, or the sudden occurrence of a trivial matter of no special tendency, would overcome her with a "hot bloom"; an almost constantly-besetting tremulousness of body, apparently capable of imparting a certain tremor to the mind also; which in the severer periods of ague displayed itself in excessive shivering and seemed superficially, from

its association with the sensation and often with the reality of great cold, to be attributable to chill ; but was often felt and noted in the other vicissitudes also ; so that it must have had a deeper and more permanently irritative cause, than cold alone ;—a certain inward tremulousness, described by herself as a “trembling in her bowels,” was seldom altogether absent ;

an inordinate degree of exudation of moisture from the skin ;—a perspiration that was not the result of any exertion and was almost continually present in some measure ;—most profuse during the period of the declension of a stage of fever ;—still continuing in slight degree in the subsequent quiescent condition ;—sometimes excessive in a quasi-passive manner even in the period of extreme ague ;—and disappearing, or nearly so, only in the hottest onset of the fever ;—but I doubt whether it was ever altogether absent from the entire surface of the body ; and sometimes it was accompanied with feelings so oppressive, combined with her shortness of respiration, that she would declare herself to be in “a stifling heat,” when yet her temperature was much below 98° ;

temperature of body persistently, and in all conditions, very low as compared with the normal standard ; shown by the thermometer, carefully placed and sustained deep beside the root of the tongue, to range commonly from below 94° F. to 97° ; seldom reaching 98° ; and only once, in a feverish period shortly before her death, observed as high as 99° ;

micturition varying ; sometimes very scanty ; generally pale and clear ; recorded once, a week before her death, as “loaded with lithates,” when her temperature at my visit was 95·9° F. ; late in the case some œdema appeared below the knees and in the hands, probably caused by some impairment of the secreting tissue in the kidneys, combined with debility of the nervous system ;

the end came thus:—after having, it was said, seemed a little better for a while, she took some nourishment about 2 a.m.;—a little later she grew feverish,—delirious,—restless;—near 4 a.m. she asked to be raised in bed, probably in hope of freer respiration, and was so;—very soon after that she simply ceased altogether to breathe,—and was dead;

there was no post-mortem examination.

2. The second case which I quote is that of a woman, younger and less asthenic than in the preceding case, of about 35 years of age,—whose dwelling stood on the margin of an extensive tract of swamp, laid out in “water-meadows,” in a long, low, very wet alluvial valley, in which a dense foggy atmospheric stagnation alternated with cold winds, and through which a small sluggish stream flowed and kept the mud wet. The case was under my observation, not quite continuously, for nearly three months in a rather hot summer.

Severe febrile suffering and inability to take food or retain it made her send for me. But, further, she was in a very debilitated state of long standing, anæmic and ill-nourished, weak in body and dull in mind. She had suffered from malarial disease for many years, “cold chills” habitually predominating, “hot flushes” often passingly accentuating them. The thyroid was exceedingly enlarged, and very painful in times of fever; had been an unsightly swelling for fourteen or fifteen years. Spleen also much enlarged, and at times, in the presence of any degree of fever, very painful; habitually felt, as a weight in her falling backward, when she lay back in bed. Had suffered from phlegmasia dolens after a confinement two years before.

The present exacerbation of her condition she dated from a time sixteen days before I saw her, when she was

seized with unusually cold chills, a catamenial period being then current; but she was able to be up and about a little until two days before, when, feeling very chilly, she took a little brandy (*not* an accustomed thing) to bring pre-hance some little glow of warmth to her; which, forthwith, had results beyond what she looked for, exciting severe intermittent fever, extreme alternations of hot and cold, great suffering, and some recurrence also of the catamenia.

The symptoms noted during my observation of the case were:—pulse permanently very small and weak, and somewhat rapid, from 82 to 108 beats in a minute; tongue never clean, sometimes very dry and “nasty,” generally furred, coated and slimy;

fauces and gullet filled in mornings with thick tenacious secretion, causing her to cough and retch, and, until it could be more or less dislodged, preventing her taking food;

stomach very weak, at first very irritable, sometimes vomiting foul mucus, tainted with gastric secretions and bile;

bowels evidently costive by habit, but easily excited to action by medicine or even by the coming on of the irritation of fever;

profuse sweating, noticeably more profuse during the quiescence and decadence of a stage of fever;

a troublesome rash, of little bright red points, quite thick, with extreme pungency of stinging and pricking, thickest and worst on the parts which were hottest and most perspiring, on her back, bosom, sides, &c.;

inability to go to sleep, after long wakefulness falling asleep towards morning sometimes, then sleeping heavily and awaking in a profuse sweat;

head “queer” and giddy, chiefly in morning;

the temperature, shown by the thermometer applied in her mouth, was lower than natural. At my first visit, notwithstanding such symptoms of a fevered condition, as the pervading sensation on her own part of being unnaturally hot, painful aching of back and limbs, restless inability to lie still, severe pulsating headache increased by movement, mouth very dry, and great thirst which she in vain tried to slake by taking tea, (which her stomach would not tolerate), the temperature was no higher than 97·8 F. Next day, the fever being worse, pains more severe, goitre very distressing with its tension and weight, no sleep, stomach rejecting everything, tongue foul and slimy, the temperature was 101·1 F. After this the temperature declined; was not again above 99·5 F.; nor was it again, during the course of my visiting her, so low as on the first day; not observed lower than 98·3 F. But, reasoning from the distinct evidence, which I had, of a feverish condition being present even when the temperature was so low, it must be supposed that the habitual, non-febrile, temperature,—the temperature which in the course of so many years of exposure to malarious conditions had become natural to her,—was lower, perhaps considerably lower, than the first temperature noted in the fever; and it was made evident, in eliciting her history, that a cold condition, including abundance of “cold chills,” was a much more accustomed, much less remarked, much less disturbing, experience with her, than was any state of fever greater or more prolonged than mere fugitive “hot flushes.” It is also to be observed that, although when fever was present, such as I treated her in, the two enlarged organs, the spleen and especially the thyroid, gave her much distress and suffering, yet in the ordinary tenour of her life the enlargement of these was not accompanied by more than a certain degree of

not very distressing inconvenience; and, therefore, it may fairly be concluded that, in the ordinary tenour of her life, she must have been free from any considerable dominance of fever, and most probably, in view of the temperatures when fever was present as above recorded, have been habitually of a very low temperature of body.

3. The third case to be cited is that of an elderly man, about sixty-five; who lived in a damp thatched cottage, situate in a small garden in a retired angle of the base of a considerable hill, where the exhalations from the wood and undergrowth, with which the hill was covered, descended and lay, away from any refreshing or purifying breezes. He was under my care during three successive winters; for 42 days in the first; 80 days in the second; and 3 days only in the third, which ended in his death.

During the first of these periods the following conditions were noted;—in person, thick set, somewhat slow and deliberate in movement:—

countenance unnaturally pallid, not flaccid,—outlines of features somewhat lost in a general flattening and filling out;—

manner slow and placid, yet somewhat pained;—

pulse always slow, ranging from 60 to 68 beats in a minute;—

suffered much from distressing pains, all over and through him,—in back, limbs, chest, belly,—worst in the night;

warm in bed at night, not too warm;—

had seizures of excessive cold and shaking every afternoon;—

warm in bed at night—did not complain of being too hot, even in bed, until, after about a fortnight's treatment, he began to feel a little stronger:—

temperature always low, ranging from 96·8 F. to 97·8 F., till just before my attendance ceased, when it reached 98·0 F.:—

tongue broad, exceedingly pale, looked as if subject to some fatty or similar degeneration, furred, coated white:—appetite said to be fairly good:—

fulness, pain and tenderness at pit of stomach,—much flatulence, both ascending and descending,—windy colic:—action of bowels costive and insufficient:—

not much thirst;—

urine thick with mucus, abundant in lithates, sometimes had pain in bladder before micturition;—

had very little sleep.

In the second winter my notes record the following:—very pallid,—lips white,—looking bloodless generally,—with a general contour and gait, as of thickened textures,—broad colourless hands and fingers,—heavy-headed and dull in appearance;—

pulse sluggish, sometimes becoming a little excited under observation, weak, uncertain, soft, usually from 60 to 70 beats in a minute, but sometimes more frequent, even up to 85 beats;—

general weakness very great,—sometimes “limbs so weak he could hardly stand,”—“weak and cold about the knees”;—

cold chills continued a daily experience,—with shiverings,—sometimes oftener than once a day;—generally felt chilly;—

late in afternoons sharp pains came on in bowels and limbs, which continued for nearly twelve hours, commonly from about 5 p.m. till about 4 a.m.;—

generally very hot and feverish in nights,—sometimes perspiring,—sometimes shaking at the same time;—

temperature on the whole higher than in the preceding winter,—once was noted as low as 97·0° F., but on a second trial after a clear space of two minutes the thermometer, which I always kept carefully lodged in the

month for more than a minute, showed it to have risen to 98·2° F., by reason probably of some slight degree of nervous disturbance caused by my visit and investigation,—the highest recorded was 99·2° F., at a time when he declared himself to be “feeling better”;—

tongue continued of the appearance described above, pale, broad, flabby, furred, white, and slimy;—

fauces and trachea hampered by thick secretion, which he coughed free and spit up with difficulty;—

appetite poor,—pain and tenderness at ensiform;—

bowels very costive,—hardly any action without medicine;—

spleen always painful;—

urine generally thick, loaded with lithates and stringy mucus;—

power of sleep small, but improved latterly.

In the third winter, I was summoned to see him one evening and found him in bed, with much distension of belly and in great distress,—been previously sitting by the fire,—not been out that day;—

been “feeling bad” for several days,—pains in belly, in umbilical region chiefly,—numbness in hips and down to knees,—shivering a great deal,—very hot and sweating in bed at night;—

the myxœdemic characteristics of face, hands, and general condition and contour, of the winter before, were now much more conspicuous and advanced;—

pulse more rapid, 110 beats in a minute;—

respiration very short, 30 in a minute;—

temperature 98·4° F.,—not then feeling hot,—not particularly thirsty;—

tongue broad, pallid, furred, coated, slightly frothy, reddened litmus paper sharply;—

eructating much wind,—belly distended and loudly tym-

panitic,—bowels, habitually very costive, had acted early the day before, a loose dark motion with much wind ;—urine scanty, reddish, with much grey sediment ;—slept very little in previous night ;—next day :—pulse smaller, weaker, 116 in minute ;—temperature 98·9° F.,—not feeling hot,—had not sweated in night,—“ feet none too warm,”—rather thirsty ;—tongue as the day before ;—belly distended still,—bowels not acted ;—urine scanty, loaded with lithates ;—had several snatches of light sleep ;—shaking so as to be unable to raise cup to lips for himself.

After this,—although some defæcation was accomplished by the use of enemata in addition to medicines by the mouth,—it failed of being effective ; and on the fourth day,—when on the close stool after the administration of an enema,—he seemed to be embarrassed with “ phlegm ” in his throat,—asked his brother to raise his head for him,—and died.

4. The fourth case is that of a man, whose dwelling, on the margin of a village, stood in the bottom of a very damp, commonly foggy, alluvial valley, whose soil was greatly composed of the accumulated surface washings of a large district of oolitic limestone and chalk, and was kept wet by a sluggish stream meandering down its midst. He was about sixty years of age, when I first saw him,—a working man of high respectability, but of somewhat peculiar appearance ;—a pale, immobile countenance,—a stolid, gentle expectancy of look, associated with dulness of hearing,—a quaint, simple impressiveness, almost difficulty, of utterance and enunciation,—an angularity of gait and general slowness of movement and demeanour,—and noticeable hands and fingers, broad, wooden-looking, colourless and “ spade-like.” He was under my treat-

ment and observation many separate times during the course of six years,—sometimes only for a day or two,—sometimes longer,—and once for so long as twenty-seven weeks continuously.

In the earlier times the following conditions were noted:—

pulse small, weak, uneven;—

general physique much weakened, often very weak,—had formerly suffered from rheumatoid arthritis in wrists and ankles;—

temperature commonly very low, about 97.7° F., rising when fevered to 99.3° F.;—

subject to cold feet, general coldness, drowsiness (without headache), aching pains in loins and limbs, cramps in legs;—

liable to frequent severer cold seizures, characterised by shiverings, extreme pallor and pinching of countenance, severe pains in belly, and constipation;—

liable also, but less frequently, to feverish attacks, mostly in bed at night, with profuse sweating, and at the same time sickness of stomach;—

occasional wheezing in trachea;—

tongue very rough, often dry, or foul;—

habit of windy eructation,—heartburn:—

very costive and inefficient habit of bowels;—

frequent necessity, with want of natural energy, of voiding a pale, clear, not very copious, non albuminous urine.

In the last three years—the above conditions showed considerable increase in evil significance;—the general appearance of the patient was more infirm,—the palor of the countenance more fixed,—the energies of mind and body more depressed and slow,—and his actual strength diminished;—

the pulse small, weak, uneven, sometimes intermitting, of

very variable frequency, once only 60 beats in a minute, and once, in fever, as many as 105 ;—
 temperature generally low,—in 15·15 per cent. of my observations was below 97·0 F., once among these being only 94·5 F.,—in 43·93 more was below 98·0 F.,—in 27·27 more was below the normal standard of 98·4,—in 9·09 more was below 99·0 F.,—and of the remaining 4·54 the highest was 99·4 F. ;—it varied with great rapidity, and was influenced sometimes to an unexpected degree by apparently inadequate circumstances, as,—for one instance,—it was a practice of mine sometimes to take a second observation with the thermometer in about three minutes after the first, if that first was in any way remarkable, and I found on several occasions that the second observation read much higher than the first, owing I believed to a certain nervous excitement induced mentally in the patient by the little-understood proceeding, the attention so pointedly directed on him and an untutored apprehensive concern it created in him, acting on an already existing condition of irritable nervous instability,—on two such occasions the difference between the first and second reading was as great as 2·5 F. ;—and for another instance,—two hours before I saw him on one occasion he had been suffering so much from distressing coldness (—this of course was gauged by his own feelings of distress and not by the thermometer, but there was reason to believe that he had been in a condition of severe real depression of physical temperature), that he had had more clothes heaped upon him in bed, in consequence of which, half an hour before my visit, he had become exceedingly hot and feverish, with head badly aching, and when I arrived, though no longer “feeling hot,”—the temperature was the highest I had recorded, 99·4 F.,—such variations would of course involve a little error if it were

attempted to calculate and state an average temperature from the observations recorded, but no average would be of any value, compared with the remarkable trait of such a variability;—

he had shiverings at times, not always when the temperature was very low, nor only then, but sometimes concurrently with his feeling too warm; he complained also sometimes of twitching in his limbs as he lay in bed; and suffered occasionally from very painful cramps in his legs. These three phenomena, it appeared, might have been but different grades of manifestation of the same general condition of interstitial irritation of nervous elements by an irritative poison; or, the cramps might have been due to intestinal irritation from the hardened and continually flatulent results of an inveterate costiveness; and the twitchings might be deemed either a milder form of the cramps or a development of the shiverings:—

sweating—came very easily to him,—and the hot attacks, which generally came on in the night in bed, resulted in profuse perspirations, in which the fever passed away,—while these continued for sometime in some degree after the temperature had been lowered again:—

breathlessness—was an ordinary topic of complaint,—a want of power of respiration, which became laboured and very short on exertion,—there seemed, as it were, some inelastic and inexpandible restriction on the capacity of the lungs,—some wheezing and occasionally some slight râles were at times to be heard,—but there was not a trace of any inflammatory action:—

coughing—with more or less of expectorating effort and of straining to dislodge a thick and tenacious secretion—was common,—but was not always coincident in its severity with severe shortness of breath,—appearing at times associated with a very costive condition of the bowels and

a very low temperature,—and getting easier, along with freer and sometimes more abundant expectoration, concurrently with profuse sweating :—

tongue—generally rough, furred, white, and dry,—reddening litmus paper, as did also the lips,—sometimes foul, coated, or sticky,—sometimes shrivelled looking, parchment tinted and rugous,—also exceedingly pale, with an apparently sub-mucous paleness, moist and indented ; one time, after about seven months had elapsed without my seeing him, he was reported to me as “ speechless ”—and, on going to see him, I found he was unable to utter any word distinctly or to articulate any but labial sounds, and had been so all day, on account of the condition of his tongue, which was swelled, indented with distinct prints of his teeth, stiff, very pallid and moist ; he was in no pain, but unable to get down any food and much troubled with ‘ phlegm ’ in his throat ; these conditions disappeared under treatment, but it was the commencement of my longest term of treatment of him ; very commonly he complained of a bad taste in his mouth and his breath was very offensive :—

fauces and larynx were together involved in a thick, tenacious and foul mucous secretion, which impeded deglutition and gave rise to incessant efforts of dislodgment :—

a similar condition seemed to extend down to the stomach and to be the cause of flatulence and acidity, with pain and tenderness at the ensiform, seriously impairing the appetite and capability for food :—

bowels were habitually costive and inert —sometimes painfully racked with flatulence, which was most severe in periods of ague :—

urine was prevailingly pale and clear,—sometimes depositing lithates,—generally copious enough, sometimes scanty, without much relation to the presence of lithates

or the reverse;—but a remarkable feature of micturition was the apparent loss of power in the bladder,—he had no stricture, no sensible spasm, nor feeling of obstruction, no restriction of flow, nor smallness of stream,—but apparently an incapability of applying that proportion of voluntary energy *a tergo*, which ordinarily initiates and supplements the organic function,—to use his own expressions, it was very “long in coming,” then came “freely enough,” then power was wanting to “finish properly,”—enlargement of the prostate could not account for this,—the default seemed to lie in the condition of the walls of the bladder:—

thirst was not infrequent,—was not closely related to the presence of fever,—was probably more often only dryness of mouth, due to the condition of the cavity, than any general want of the system,—was seldom much relieved by taking fluid:—

the faculty of sleep was much impaired,—sometimes he had little sleep for many nights:—

The course of the case on the whole, throughout the six years, was but a persistent decline from bad to worse,—an ever-advancing invasion of the powers of life by the evil conditions due to the working of the poison of the malaria, in which the patient continued to reside.

5. The fifth case—is that of a young girl, not more than eighteen years of age,—whose dwelling had hitherto been in the same hamlet in which the subject of Case III. resided,—but who was now living in household service about a mile and a half distant from that and in a more open and exposed place. In person, she was of short stature; fairly well-nourished, though by no means plump of body; appearing always deficient in colour, and sometimes very pallid and sallow of countenance. She had been habituated to all the ordinary experiences of a ma-

larial existence,—frequent and prevailing cold chills, from time to time relieved or accentuated by accessions of hot flushing or fever,—passive sweating, &c. ; was already the subject of some considerable enlargement of the thyroid ; suffered, not uncommonly, a good deal of pain in the spleen, which was also somewhat enlarged ; and her ovaries were apparently affected by a similar condition of enlargement, causing considerable local suffering at times, embarrassing their function, and producing such disturbances of general well-being, as naturally follow imperfect menstruation. During about a twelvemonth she very frequently came under my notice and treatment ; and in that time I had occasion to note the following :—

pulse—generally rapid, weak and small,—sometimes irregular or uncertain,—very variable as to frequency, noted as low as 76 in the minute, as high as 128, and in over half of the recorded observations 100 or more ;—

temperature—also varying greatly, ranging under my observation from 96·2 F. to 102·1 F.,—very low (averaging about 97·2) on those occasions when she was feeling better than usual.—Feelings of unnatural chill were of ordinary, and therefore of little remarked, occurrence ; more rare than they and more disturbing were feelings of unusual, or even excessive, heat ; but not always did feelings of chilliness or feelings of warmth on the part of the patient give a true indication of, or indeed have any relation to, the actual temperatures, as shown at the time by the thermometer.—Shivering is a symptom which naturally conveys to the mind, both of a patient and of an observer, the idea of chilliness ; and this symptom was frequently present,—not only, however, when the low temperature attested by the thermometer seemed to show good reason for it,—but also when the temperature was not very low, or even was very high, and when the patient was sensible

of being warm—In like manner the phenomenon of sweating is ordinarily noted as a symptom of warmth of body, and conveys that idea; but it was occasionally present in this case, not only when the temperature ascertained by the thermometer was high, but also when it was low,—on one occasion when it was no higher than 96·9 F. These circumstances therefore pointed evidently to a two-fold character in the poisonous cause underlying them,—a cause which with its irritancy excited a general disturbance of the organic nervous elements, tending to produce among other issues an elevation of temperature, at the same time that it exercised a power of overcoming that elevation and even of farther depressing the temperature,—a power of damping down the combustion in the tissues, on which the maintenance of the temperature and other beneficial processes are dependent;—

headache—very frequent and persistent,—sometimes very severe, especially when the temperature of the body was high,—sometimes apparently brought on by taking food;—tongue—always anæmic,—generally moist, or slimy,—rarely dry, except on waking in mornings,—in ordinary times of low temperatures appearing small, soft, smooth, light coloured, with a look on the surface, especially at the sides, like the bloom on a red plum,—in times of high temperatures much furred, coated, frothy, sticky—and almost always, whatever the temperature, giving a clear acid reaction on blue litmus paper, as also—even more sharply—did the lips,—a bad taste in the mouth was very common, especially on waking in the morning:—

cough—sometimes present—no râles in chest—apparently due to the irritation or discomfort of an adhesive secretion in the fauces and larynx;—a similar condition seemed to extend thence downwards to the stomach,—tenderness on pressure, or on the effort of coughing, below the ensiform,

—feeling of exhaustion, sometimes with sensations of fluttering, at præcordia ;—

appetite variable,—sometimes very weak,—best at times when the temperature was low ;—

bowels—frequently constipated—more often so when the temperature was high, than when it was low ;—

urine—generally natural and clear,—sometimes very thick with lithates in periods when the body temperature was very high,—sometimes scanty and pale, when the temperature was very low :—

catamenia—feeble, irregular, imperfect,—the term of recurrence calculated to be natural to her was 26·8 days, or nearly,—but any appearance of flow was developed only four times in ten months, each of these times very slight, once a little too late and very slight indeed, and only once lasting into a second day,—though some other periods, in which there was no ‘show’ whatever, were recognizably indicated by the manifestation of some of the specific suffering and nervous disturbance commonly incidental to menstruation. Both the ovaries, but principally the left, were prominently enlarged and indurated, and were the source of much suffering ;—the left almost continually gave her pain ;—the suffering became much aggravated on occasions when the catamenial function was comparatively effective, and on occasions when feverishness was betokened by unusual temperatures, and sometimes with the coming on of evening. Hysteria showed itself sometimes,—once or twice to a considerable degree ;—generally seemed connected with the catamenia, either present, or impending, or just gone by :—

thyroid—was greatly enlarged, for her age,—forming a flattish swelling across the front of the throat, largest inferiorly and to the right side, about five inches broad,—slowly becoming larger as months proceeded, not by a

steady growth, but more by occasional spurts of enlargement, which seemed not unconnected with menstrual efforts:—

spleen—was enlarged,—tender to pressure,—often the seat of aching pain, now and then very severe, seemingly brought on by accessions of feverishness and increased temperature:—

besides shivering stages of chill and visitations of fever and peculiar sufferings of particular organs, there were, during most of the time, frequent minor phenomena, which indicated the presence in the tissues of an irritation only attributable to the poison of the malaria;—sleeplessness, excessive dreaming in sleep, and the persistent aching of back and limbs. Of these three the last was the most common, and it did not seem to be peculiar to any of the variations of temperature; the sleeplessness, however, was associated with temperatures higher than the degree which seemed to have become normal to her; while the excessive dreaming during sleep, appearing to be but a modification of the sleeplessness, was connected with temperatures below that degree.

6. As a sixth case I select one, in which the main feature is the very early age, at which the effects of malaria were evidenced. It is that of a babe at the breast, the child of parents who lived in the same village as, about a hundred and fifty yards from, but in a somewhat better position than, the man who is the subject of Case IV. She—it was a female child—was under my professional care for a short time when she was barely three months old and again for a little longer time about five months later. The first of these two periods began with my inspection visit after vaccinating the child, when I found a perfectly successful result of the vaccination, also an upper incisor coming through, but therewith the

malarial conditions which I propose to detail. At the second period dentition was, and had been, progressing with some rapidity and also facility; but the conditions, on account of which my attendance was desired, which I am presently to detail, were not to be accounted for by the dentition. Nor does it seem that any of the phenomena of either of the two periods were attributable to the dentition, except that an excessive flow of saliva belonging to the first period and a great degree fretfulness belonging to the second may have been due to it, in part if not altogether. The conditions observed in both periods were so much the same and of such apparent continuousness, as to make it proper to present them in one record; as follows:—

frequent marked changes of evident states of body,—often becoming exceedingly pale and cold,—then rapidly getting very red and hot—and sweating profusely,—in the first period the sweating seemed confined to the back of the head and neck,—in the second period the special localization of sweating at the occiput was gradually lost in the general exudation over the whole surface;—

temperature—was noted in the first period as low as 96·4 F., notwithstanding the concurrent presence of ripely developed results of vaccination,—and in the second period as low as 97·3 F.,—these temperatures were taken at times when she was neither in extremity of heat nor in extremity of chill,—and a similar mean taken in the later part of the second period, when she was getting comparatively well, showed only 97·5 F.;—

great fretfulness—probably not due, more than in part, to dentition,—being manifested only in the second period,—not in the first period, when the dentition was already in progress,—probably due, in great part at least, to the harassment of the feverishness and nervous irritation produced by the malaria;—

tongue—soft, moist, pallid, sometimes almost bluish ;—
excessive discharge of saliva in the first period,—*i.e.*, of
fluid from the mouth including a proportion of true saliva,
—due probably to something more than simply the coinci-
dent dentition, which was still in active process through-
out the second period,—due, partly at least, to an exag-
gerated secretion of mucus in the mouth, related to and
continuous with what occurred, more abundantly later, in
the parts at the back of the mouth ;—

excessive mucous secretion,—developed before the second
period,—in both pharynx and larynx,—causing frequent
efforts of coughing to dislodge it,—sometimes voided suc-
cessfully only by vomiting,—present also at times in the
air-passages,—giving rise to apparent tightness of respira-
tion and occasionally to audible wheezing,—also relieved
by coughing ;—

bowels—persistently costive,—with rare occasional bilious
motions ;—

urine—natural in the first period,—very staining to her
linen and very high-smelling in the greater part of the
second period.

These six cases of malarial disease are but a few out of
very many, with which I have been professionally asso-
ciated. They are far from affording a complete repre-
sentation of the phenomena of the disease ; but they are
typical instances of a sufficient width of scope to serve my
present purpose, in that they show, as the indubitable
actual results of malaria, many of the identical conditions
which I have previously described as reasonably to be
expected from the acknowledged essential nature of ear-
bonic acid and its actions on the living animal organism,
and in so doing to add a reasonability, of great urgency,
to my identification of the poison of malaria with that gas,
which, further, is the only known hurtful constituent of

the atmosphere that is present in all known malarious situations and is capable of these effects. In like manner, too, as these few instances come short of affording a complete study of malarial disease, they also come short of exemplifying the detail, which I have endeavoured to elaborate, of the results of slow continued poisoning by a carbonic-acid-laden atmosphere; but my claim is, not that these cases are an adequate illustration of the effects of malaria or of carbonic acid, but that my previous exposition of the natural modes of action on the organism of a gradual imbibition of carbonic acid is of much wider effect, is conterminous with the whole range of malarial disease, and supplies or indicates the means of explaining, not only the symptoms and conditions which have been instanced in these cases, but all the phenomena of impoverished and depraved health which are attributed to malaria.

SECTION V.—Along with the development of such an argument, as that which has been approached, studied and illustrated in the foregoing pages, there has of necessity also been an ever pressing question,—Will the identification of the poison of malaria and the exploration of its natural modes of action be likely in the end to afford guidance towards a more reasonable and scientific and beneficial treatment of malarial disease, than the purely empiric methods of treatment in general use? I confess that, in the observations of phenomena, the speculations and attempts, which in my professional experience of the disease it has occurred to me to make, and in the views which these have established in my mind, I have always looked forward with some assurance to this question being answered in the affirmative. I venture therefore to proceed to the suggestion of some principles of treatment, which are based on my experience, which I have now no

longer the opportunity of following out and developing further in professional practice, but which I think are true, so far as they go, and capable of leading on to the scientific treatment, which would be so desirable.

Let me commence doing this with some remarks about quinine; whose virtues, or the virtues of its parent cinchona, were first discovered in relation to malarial fever, and have, ever since, been extolled, as a specific remedy in malarial disease, with an insistence and exclusiveness, which I think has been misleading. It is certainly true that quinine is capable of great effect in subduing the febrile conditions that are excited by malaria; but, as I have endeavoured to show to be the case, febrile conditions are but a small and inconstant part of malarial disease, and, if they have come to be regarded as a chief feature of the disease, so that it, as a whole, has been looked on as a "fever," called distinctively 'intermittent' because its feverishness seemed to vanish intermittently, it is because the febrile conditions appear to be the most striking and sensational to the common appreciation and have therefore received an undue proportion of regard. On that other equally interesting state, from a student's point of view, of organic nervous irritation, which is manifested in involuntary and uncontrollable shiverings, which is as common and as incapacitating, though not dramatically so striking and alarming, as the fever, quinine has not nearly so potent an effect, although it can reduce the shaking a little. But on the underlying conditions and processes of the disease, whether in its earlier or in its more advanced stages,—on the lowering of vitality, of temperature, and of physical energy,—on the vitiation of secretions, the thickening of tissues and the enlargement of organic structures, &c.—quinine exerts no remedial influence whatever. Nor,—if the contention, that the

active agent in malaria is carbonic acid, be accepted,—is it difficult to assign reasons for these limitations of the beneficial action of quinine; for,—although we are right in ascribing to it a power of supporting or steadying the nervous system against the intimately diffused irritation of the poison, whether by stimulating the inhibitory functions of the cerebro-spinal nerves, or by subduing directly the excitability of the organic nerves, and so of reducing the fever and alleviating the rigors,—yet we cannot recognize in it the existence of any of the characters of an eliminating agent, which would enable it to carry off, or to cause the expulsion of, the poisonous acid from the system.

It was however the accepted practice to give quinine in malarial disease, irrespective of there being any fever or not; a practice to which for a long time I felt myself constrained to adhere. Pursuing therefore this practice and using mineral acids, sometimes hydrochloric, sometimes sulphuric, to dissolve the quinine for the better administration of it in the convenient form of mixture, I found that, when hydrochloric acid had been employed for that purpose, there was a result on the temperature of the patient, which was raised a little and made to approach more nearly by a little to a natural standard; but that no such result ever followed the similar employment of sulphuric acid. Hence it appeared to me that hydrochloric acid must be possessed of some specific potency, which made it effective, in however limited a degree, as a remedy against one of the most characteristic of the effects of malaria, and that it might be good for more.

There is also a commonly received statement, which has a direct bearing in support of such a conclusion. It is said that on 'mangrove swamps,'—those hideous wastes of sea-laved black and greasy mud, whereon almost

the only forms of life are the mangroves and a little human population,—there is no malaria, or at least its effects are not known to the dwellers there. If this be true, as I believe it to be,—if there be such an immunity in such a place,—it seems necessary to credit it to some quality, or qualities, inherent in the briny moisture of the sea, penetrating into the soil, and exhaling into the atmosphere the ‘elements,’ combined or free, which from this origin have received the name of ‘haloid’; and to these ultimately to ascribe the power of counteracting any malarious poison in the emanations of the situation. I think it is likely, that it is not in a state of absolute freedom, that these haloid elements are thus shed into the atmosphere, but in combination at least with hydrogen, and that they are—so to say—administered to the soil, by the sea-wash, in those forms of combination, in which they exist in the sea, as chlorides, bromides, iodides and fluorides; which also are the forms, in which they may be most conveniently administered in our therapeutics.

To these salts and acids, therefore, of ‘haloid’ origin I gave my faith, as probable antidotes, in some part or degree, to the poison of malaria; and I had the eventual satisfaction of finding that the results of their use in the treatment of many advanced cases justified my faith. I employed chiefly the chlorides and the bromides; the iodides I did not find to have much specific effect on malarial conditions; and the fluorides I knew little about and did not have recourse to them. Later, although the iodides had disappointed me, I had some reason to believe that hydriodic acid, uncombined, possessed some of the desired efficacy.

Of the chlorides I found the most useful to be those of ammonium, iron and sodium; although the chloride of potassium was sometimes found useful in impeded intes-

tinal action, and the perchloride of mercury had a favourable effect on the glandular organs connected with the digestive tract and also, I think, on the kidneys.

I selected first the chloride of ammonium because it appeared probable that this base, in virtue of its own constitution, would harmlessly yield itself in decomposition to the formation of some substances not foreign to the system. This salt seemed to affect specially and everywhere the mucons membranes, on the secretions of which it exercised a liquefying effect, enabling them, as I thought, to carry off some portion of the peccant poison and, at the same time, liberating the discharge of natural functions. Perhaps a slight and passing primary stimulating effect was also exercised by its base until its decomposition.

Of the perchloride of iron, while the base was separated and carried away down the intestinal canal, the acid seemed to be conveyed into and to affect some of the more substantial structures,—as the ovaries, the thick tendinous aponeuroses, the kidneys, and even, I think, the lungs,—apparently effecting some solution and elimination of the material abnormally thickening or indurating their areolar tissue, which had resulted from the action of the malaria, and rendering their condition somewhat more free again for the easy performance of their functions.

The chloride of sodium I found also to possess a similar specific efficacy on the same malarially induced conditions in other solid organs, especially in the spleen. But its most remarkable effect was the powerful influence, which it had in raising the low temperatures of my patients; in in which it excelled the other chlorides, although all of them had this effect in some degree.

Of the bromides the one which I commonly used was that of ammonium, in preference to the bromide of potas-

sium, its base being safer, and its use not being so frequently followed by headache as the other. It had not so distinct an effect, as the chloride of ammonium, on the mucous surfaces, nor as the other chlorides on the condition of more substantial structures; but it had a remarkable power of both quieting the shiverings of ague and restoring a warmer degree to the temperature of the body; and, in having unfailingly these virtues, I found it a most advantageous medicine.

In the employment of all these salts,—chlorides and bromides,—I had always before me the hope that, in some way and in some degree, they ousted, or led to the ousting of, the malarial poison from the tissues; and I am in the belief that they did so. At any rate their effects, such as I have described them, had a certain permanency and substantiality, until the malaria had time again to invade and overpower the organism as before.

As an auxiliary to these, observing that belladonna increased the rapidity of the pulse and respiration, I thought this also offered a means of furthering the expulsion by expiration of the poison from the circulation and thereby from the whole body; and I employed this drug for this purpose in some cases with appreciable success. But it is not a medicine fit for prolonged use, as, while quickening the action of the heart, it also weakens it; and there is a further speculative consideration, which is against its acceptability as a specific agent for the elimination of carbonic acid; which is, that, in the same way as it favours the expulsion of this acid by making the expiration more rapid, it favours likewise the increased production of it in the tissues by making the inspiration more rapid and so increasing the supply of oxygen. I therefore made but limited use of it.

An alkali, too, it would seem to first thought, should be of service to neutralize a portion of the acid poison and perhaps by combining with it make possible its elimination through the natural channels. But, after some trial, it was found, that,—although a dose of a caustic alkali would relieve in some measure for a time the distress of agueish shivering or a slight feverishness,—yet this relief lasted only, or not quite, so long as the alkali was present in the body; and that, when in the natural course it had had time to pass through and be voided, no good effect remained. It seemed to be voided alone from the system, and to leave behind it the poison as before, or with unappreciable diminution, having only rendered it quiescent while it abode with it. The eventual result was no benefit in regard to the disease; and the temporary mutual neutralization—or combination, if such occurred—in the system, which gave the passing relief to the patient, did not prevent the weakening effect of the alkali on the whole organism. This was sufficient to condemn the employment of such remedies for the purpose; and it seemed to indicate also, that the agency, which was desired to dislodge the poison and facilitate its removal, should be sought for, not in any alkali, but in some mineral acid, combined or free, of simple constitution, directness of action and power superior to that of carbonic acid; such a conclusion being, indeed, in accordance with the already ascertained results of the employment of the chlorides and bromides.

Arsenious acid is well known and recommended as a valuable medicine for malarial disease. But it is not applicable to all the stages and conditions of the disease. The ultimate manner of its action is obscure, but its effects are open to observation. It seems to regenerate in some way the condition and functional vitality of the tissues which it affects; stimulating secretion and elim-

ination; restoring freedom and elasticity to the skin and areolar tissue and perhaps to other textures, acting as a solvent to their waste material; and improving in some respects the quality and energy of the circulatory fluid. I found also that it had a reliable effect in raising to a more natural level the low temperatures, that were so prevalent in chronic and asthenic malarial patients. I therefore employed it, and with signal advantage, in cases, where low temperatures were habitual, and where the thickening of enveloping and cellular structures, which I have previously instanced, was present. But I found it inadmissible in those other cases, of a comparatively sthenic vitality, in which high temperatures were developed. It often, moreover, seemed to produce headache, and also constipation of the bowels; and its deobstruent energy did not appear to be equal to that of the haloid salts; so these considerations, as well as its dangerous character as a cumulative medicine, frequently restricted me in its employment.

Sulphuric acid, as I have shown above, did not, as did hydrochloric acid, manifest any corrective influence on abnormally low temperatures. I found afterwards that the tendency of its operation is in quite the opposite direction; it was probably reduced in the system to some lower grade of chemical composition, and exerted the depressing influence, which is common to sulphur and others of its compounds; it proved to have a reliable effect in lowering temperatures unnaturally high. And its use for this purpose seemed to be recommended by such considerations as the following;—that, whatever the grade of composition to which in the system it was reduced, it would probably still be capable of ousting from the tissues some of the carbonic acid, and was itself afterwards removable.

Ergot is another medicine, the last which I need here mention, possessing a specific efficacy, which I found of

peculiar service against some malarial conditions. It had a powerful and ready effect in reducing as it were by squeezing, the enlargement of some solid organs, and in overcoming by this means the pain caused by their distension. In my experience, it speedily relieved the agony of enlarged spleen; reduced swelled tonsils; eased tumefied and aching ovaries; and on moderately enlarged thyroids had perceptible effect. It also had a decided influence in bringing down high temperatures; showing by this, I think, that its effects were not limited to the boundaries of these organs.

Besides the employment of such special medicines, however, there are some other points of signal importance in the general treatment of malarial disease deserving of remark.

All the excretory powers of the system should habitually receive attention with the view of keeping them up to the full natural exercise of their function; and the greatest of them all, the defæcating apparatus of the intestinal canal, should, not sometimes only, nor even frequently, but perpetually, be made the object of skilful, watchful and judicious consideration and care.

What are commendable articles of food and drink, is a question of first-rate importance,—articles which shall serve as food to the tissues of the body and at the same time shall tend as little as possible to the introduction into the system, or the speedy formation therein, of additional carbonic acid. Nitrogenous components of food are not here in question; except that I may express my belief that the more liberal, within reasonable limits, the proportion of them is in the diet of a malarial patient, so much the better it is. In regard to other articles of consumption,—I refer both to food and drink,—there are some, which contain an important amount of carbonic acid already formed, or contain carboniferous matter in

process of conversion into carbonic acid, or are themselves only and quickly convertible in the system into carbonic acid; and there are others, which in some measure approach to the perfect conception of a wholesome carboniferous food, going purely to the growth and regeneration of the tissues, taking on their nature and vitality and functions, and only after these functions have been discharged producing carbonic acid. The latter class may be sufficiently exemplified by a single instance,—bread of an ordinary kind, if pure, well-baked and fresh; the wholesomeness of which needs not to be emphasized. The former will only be exemplified serviceably by a greater number of instances, which I do not put forward however as any full list of such articles;—‘hard’ water for drinking (but it may easily be freed from the carbonic acid, in which consists its hardness, by simple boiling), aerated waters, and sparkling fluids;—imperfectly baked leavened bread, stale pastry, beers, wines, &c.;—and alcohol, in whatever denomination of ‘spirits’ disguised;—which are all, in varying measure, detrimental in malarial disease and should be avoided.

Lastly, in view of the remarkable variations in bodily temperatures which characterize malarial disease, more remarkable in their divergence below than above the normal degree,—the serious impairment or harassment of vital energy which they entail,—and their manifest relation to changes that have taken place in the conditions of the immediate personal environment, it becomes a matter of moment to give attention to the means in use for the protection of the body and to the heat-conducting conditions which affect its environment, so that, as far as it may be possible, an equable and beneficial temperature may be preserved, in which the body may have encouragement without excitement to continue its functions at their natural level.

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